SCIENTIFIC AMERICAN SUPPLEMENT

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VOLUME LXXXV] NUMBER 2200 ★ NEW YORK, MARCH 2, 1918 ★ [10 CENTS A COPY $5.00 A YEAR

From L'Illustrazione Italiana

Moving Artillery forward in an advance on the Italian front

LIGHT ARTILLERY IN THE WAR

The Technical History of the Airplane*

How the Various Elements of the Airplane Have Been Gradually Developed

By Capt. F. M. Green

THE history and development of mechanical flight may be confined almost entirely to the present century. In the last century some success had been achieved in gliding flight, model aeroplanes had been made and flown, and at least two man-carrying aeroplanes had actually left the ground, but it was not until the year 1903 that the Wright Bros., having ended a painstaking research in gliding flight, earned for themselves the honor of being the first men to fly.

Directly the success of the Wright Bros. became known, or rather when people began to believe that what the Wright Bros. claimed was actually true, the development of flying became rapid in the extreme.

Directly mechanical flight was possible, full scale experiments were carried out, often at the risk of the life of the experimenter, and the more obvious problems became apparent. In the short space of 14 years our scientific knowledge of aeronautics compares very favorably with the world-old science of navigation of the sea.

The flying machine is an apparatus in which an arrangement of surfaces is moved in such a way that the reaction of the air provides a vertical component of the force on the surfaces equal to the weight of the apparatus. An aeroplane, as we know it, has its supporting surfaces fixed relative to itself and is driven forward by the reaction of one or more airscrews.

Besides an aeroplane, two other sorts of flying machines have offered possibilities to the inventor. One is known as the Helicopter, in which the lifting surfaces are revolved in a horizontal plane. The second is called an Ornithopter, and in this the supporting surfaces are moved in a way to imitate a bird flapping its wings. Although both these types are conceivably possible, their usefulness and practicability appear doubtful and it is only proposed in this paper to consider the aeroplane as we know it.

Nowadays we make careful measurements of the characteristics of each new aeroplane at various heights, and the word "performance" is used to refer to the speed, rate of climb, and load carried.

There are four main factors that govern the performance of an aeroplane. They are: I. The wing surface that supports the weight. II. The total weight supported in flight. III. The resistance of the aeroplane to forward motion. IV. The thrust available from the airscrew or airscrews.

As to the wings, it is necessary to know how to express the value of any particular arrangement of surfaces. The result at which to aim is to obtain the maximum vertical reaction or lift for the minimum horizontal reaction or drag. The term lift-drag ratio is, therefore, a measure of the effectiveness of a plane. Another attribute is, however, desirable, viz., that the lift per square foot of plane shall be high, so that as little surface as possible need be used for a given minimum speed of flight.

Planes vary in curve, plan form, and arrangement and number of surfaces. The designer will vary these factors according to the sort of aeroplane he wishes to make.

The Wright Bros. did not know if they would be able to fly at all. They chose deeply cambered wing sections so that the maximum lift could be obtained at the minimum speed. The lift-drag ratio of their planes was probably about 12 to 1, very much better than still earlier experimenters could obtain with flat planes. Present-day wing sections enable us to get a lift-drag ratio of 17 to 18, while model tests have shown as good a ratio as 23.

For a given minimum speed we need more surface to support a given weight than with a more cambered plane with a worse lift-drag ratio. It would be an advantage if we could vary the camber of a plane to suit the speed, and many attempts to do this on an aeroplane in flight have been made. Unfortunately, apart from increased complication, the increased weight is likely to cause greater loss than gain.

Shortly before the war an experimental aeroplane was made at the Royal Aircraft Factory, which was fitted with wing flaps nearly the whole length of the plane. These flaps could either be turned down for low speed, or up for high speed, or they could be used differentially for balancing. It was, in fact, rather a crude way of varying camber. Although it achieved the distinction of being possibly the fastest aeroplane of the day, it was eventually considered that the extra weight and complication did not justify the device.

From many considerations it appears that much improvement in lift-drag ratio is unlikely, but when the speed of aeroplanes becomes very much greater than it is today, it is quite possible that some device for changing the section of a plane during flight will be found necessary to obtain a reasonably slow landing speed.

Planes are generally made nearly rectangular in plan, but with the ends more or less rounded. The ratio of span to chord is called aspect ratio, and the higher this is made the better will be the lift-drag ratio. Here, again, it is necessary to compromise, as the bigger the span of the aeroplane the heavier will be the wings, the greater the resistance of the necessary bracing and the rapidity of the maneuvering of the whole aeroplane will be decreased. From practical consideration, therefore, the aspect ratio of an aeroplane is generally from 5 to 8; recently some large aeroplanes have gone considerably beyond this figure, but it is very doubtful if anything has been gained.

Little is known as to the effect of using planes other than roughly rectangular, but it is not very likely that much improvement will be found with planes of other shapes.

The original aeroplane of the Wright Bros. was a biplane, consisting of two planes separated by about the width of the chord. Shortly after, monoplanes, triplanes and quadruplanes were made and flown. It is fairly certain that the most efficient plane is the monoplane, for there is no possibility of interference of the planes as there is on the multiplane. A biplane, however, is probably only a little worse than the monoplane, while a triplane is a little worse than a biplane and so on. Structurally, the biplane is very much easier to make than the monoplane and, owing to this, the biplane construction has been almost universally adopted. Triplanes and quadruplanes have not had very much success, although it is quite possible that for very large aeroplanes the advantages gained in construction may outweigh the disadvantages of their somewhat low effectiveness.

From time to time suggestions have also been made that the amount of wing surfaces should be varied. This again is a complicated thing to do, and with modern wing sections there is practically never any gain in reducing wing surface; in fact, most aeroplanes would fly faster and not slower by having more surface if such surface could be introduced without extra weight or external resistance. This applies particularly to flying at heights.

The total weight that is carried on an aeroplane is obviously all-important, and it will, therefore, be useful to see what prospects we have of decreasing the weight of aeroplanes of any given type. We will divide the aeroplane into the following components: (1) Useful load; (2) motor unit; (3) fuel, oil and tanks; (4) remainder, being aeroplane parts proper.

For the purpose of general analysis it is assumed that the motors consume the same amount of gasoline per b.h.p. per hour and the figure of 0.7 lb. per hp. hour is sufficiently accurate to cover the weight of fuel, oil, tanks and pipes. There are, of course, engines which do better than this, and many which do considerably worse. It is, however, a fairly good average.

Analyzing a number of aeroplanes that have been used under active service conditions, it has been found that, apart from the useful load, the motor unit, and the gasoline, oil and tanks—the remainder representing the aeroplane proper—is very nearly one-third of the whole weight—32 per cent. being rather nearer. This weight includes the wing structure complete, the body complete with its fairing, floor, seats, controls, instruments, etc., the tail plane, elevator, rudder and fin, and the landing gear and tail skid. This weight is on the average made up as follows:

	Percentage of aeroplane parts, weight	Of total
	Per cent.	Per cent.
Wing structure complete	41	13
Body complete	41	13
Tail plane, elevator, rudder and fin	6	2
Landing gear	12	4

If we take 32 per cent. as the weight of the aeroplane proper we have the balance of 68 per cent. to divide up among the motor unit and its fuel and the useful load.

We have now only to decide what percentage of useful load we shall carry, and for what time it is to be carried, and we can find at once the weight per horsepower of the complete machine. We shall see that from the figure of pounds per horsepower of the loaded aeroplane we can get a very good idea of its probable performance.

The weights of the aeroplane parts have now been fined down to a considerable extent and except for the use of the newer materials, progress in saving weight is not likely to be very pronounced. Undoubtedly as time goes on we shall learn to make equally strong structures for less weight and the development of aluminum alloys and pressed metal construction may help to a marked extent. At the present moment wood is used very largely in the construction of both the bodies and wings. To a great extent this is due to war urgency, and no doubt aeroplanes of the future will be made of more durable materials.

The chief particular in which it is probable that weight will be reduced is in the weight per horsepower of the motor. Although progress in this respect has been remarkable, it is probable that we have not nearly reached the limit of weight in internal-combustion motors. At the present day the complete motor unit, *i. e.*, the motor itself, the airscrew, water and radiator if water-cooled, exhaust pipes, and so on, weighs generally from 3 to 4 pounds per horsepower. Certain very light motors have been made in which the weight is very little more than 2 pounds per horsepower. It is quite conceivable that in the next few years motor units of 1½ pounds per horsepower will be available, and in all possibility improvement in material will enable us to make motor units weighing not more than one pound per horsepower in the more distant future.

With regard to fuel consumption the best gasoline motors have a brake thermal efficiency of about 30 per cent.

The only motive power used today is supplied by internal combustion engines. Some day no doubt a lighter form of motive power will be developed, and it is in this respect that the most startling progress may be expected.

The resistance of the aeroplane is made up of two factors. The first is the resistance of the main planes. The second is made up of the resistance of the body, the struts, wires and fittings of the wings, the landing gear, tail plane, rudder and so forth. These can all be grouped together under the general term of body resistance. It is in respect to the reduction of this resistance more than anything else that the modern-day aeroplane owes its superiority over that of the original Wright machine.

The first man who seems to have understood the importance of reduction of resistance was the Late Edouard Nieuport, who in 1909 produced an aeroplane with a very fat body which almost completely inclosed the pilot and succeeded in making a big improvement in speed on an aeroplane of comparative small power. Since that day all modern aeroplanes have been inclosed as completely as the requirements of the pilot's view allows.

The resistance of the external parts of the aeroplane has now been fined down to a considerable extent. The various components of the aeroplane will generally be found to have the following proportional resistances:

	Per cent.
Body	62
Landing gear	16
Tail plane, fin, rudder and elevator	7
Wires, struts and fittings of the wing structure	15

It will be noted that by far the larger part of this resistance is made up of the body itself. A large part of the body resistance, however, is really used in providing cooling for the engine, whether it is an air-cooled or water-cooled engine. Whether the radiator is let into the body or is external to it does not appear to make a great deal of difference. The body is also of greater resistance than it need be, as it is necessary that the pilot shall have a good view and shall not be entirely inclosed. Bodies round in section are somewhat lower in resistance than the square bodies, but the difficulties of manufacture generally make their use undesirable. It is not likely that we shall be able to reduce the body

*Lecture delivered before the Aeronautical Society of Great Britain.

resistance to a very great extent unless we can use a motor which does not require external cooling. The resistance of the landing gear is considerable and it is difficult to see how this can be much reduced.

Another factor which influences the resistance of the aeroplane to a considerable extent is the increased resistance of the parts of the aeroplane that are in the slip stream of the airscrew. The allowance to be made for this is not known very definitely, as in either a tractor or pusher aeroplane the resistance of the body itself tends to increase the efficiency of the airscrew.

The thrust available from the airscrew varies directly as the horsepower of the motor, directly as the airscrew's efficiency, and inversely as the forward speed of the aeroplane. If the efficiency is constant the thrust available at any speed will depend upon the horsepower of the motor, consequently the weight per horsepower of the whole aeroplane is an expression for the ratio of thrust to weight of aeroplane. As in practice the efficiency of the airscrew does not vary very much, and as the resistance of modern-day aeroplanes per pound of weight is fairly similar, it is possible to predict rather roughly the performance of the aeroplane simply from the weight per horsepower figure.

There is considerable difference between the best attainable efficiency and that obtained under certain conditions.

As Lanchester has shown in *Aerodynamics*, for maximum airscrew efficiency the pitch must be a little greater than the diameter. From first principles also it is easy to see that the diameter must be a certain minimum so that the loss in the slip stream shall be small. Now it is always convenient to have an airscrew as small as possible, for when it is smaller it will be lighter and less in the way.

Again, unlike the screw of a ship, the airscrew has to work at bigger thrusts when the aeroplane is going slow and climbing than when it is going at full speed on the level. As a consequence the airscrew of a modern aeroplane nearly always has its maximum efficiency when its effective pitch is at its largest, *i. e.*, when it is going fast, and its efficiency is lowest when the pitch is small, that is, when the aeroplane is climbing.

Another disadvantage when the aeroplane is climbing is that the engine is more heavily loaded and in consequence the airscrew goes slower. With engines as they are this always means less horsepower. We need, therefore, either a change speed gear or an airscrew in which the angle of the blades can be changed. This will avoid a drop in horsepower and to a lesser extent the loss of efficiency when climbing. We also need, however, a propeller of varying diameter so that combined with a change of angle and a suitable engine speed we should get nearly a maximum efficiency under all conditions.

There is not much room for improvement in airscrew efficiency working under the best conditions, as the efficiency is as high as 85 per cent. When climbing, however, the efficiency will frequently drop to less than 65 per cent.

Attempts at variable pitch or variable angle airscrews have been made, but none seem to have reached a practicable stage. The design of such a screw is quite possible and no particular invention is required to make it a success. As the demand undoubtedly exists, variable pitch airscrews will be made successfully and will become a standard part of the aeroplane equipment in the near future in all probability.

The aeroplane flown by the Wright Bros. had a speed of 30 to 35 m.p.h., and we have in a few years made aeroplanes that fly four times as fast. What then are the prospects of the future? Before considering this we must consider the effect of height on the speed at which an aeroplane flies.

The speed drops steadily as the height is increased, *i. e.*, as the density of air is decreased. The reasons for this drop in speed are rather too lengthy to state in this paper. Very briefly, the resistance of the aeroplane and the horsepower of the engine each fall off when the density of the air decreases, but with engines as now designed the horsepower falls off faster than the resistance.

It is now proposed to consider what speed we are likely to attain in an aeroplane of the future flying at a height of 10,000 feet. As it is a hypothetical aeroplane engine, we are entitled to assume that all the improvements outlined in the preceding paragraph are incorporated into it. The assumptions we will make are: (a) That the planes have variable camber. (b) That the motor unit weighs 2 pounds per horsepower and will maintain this horsepower at all heights up to 10,000 feet. (c) That the body is the best possible shape, completely inclosed with no external fittings. (d) That the landing gear shall be folded inside the body during flight. (e) That the airscrew efficiency shall be 85 per cent. (f) That the percentage of useful load carried shall be 15 per cent. (g) That the duration of the flight shall be two hours.

Assuming that the weight of the structure is as at present, the weight per horsepower of the complete aeroplane will be 6.4 pounds. As we are considering a faster aeroplane than is at present made it may be as well to allow a little more weight for the aeroplane structure and we will assume that the weight per horsepower is 7 pounds.

We will now turn the percentage weights into pounds by assuming that the useful load is to be 450 pounds, which may be two people and luggage or perhaps one man and mails. The gross weight of the aeroplane will therefore be 3,000 pounds and the horsepower of the motor 430. We will imagine that the aeroplane is of a type in which there is practically no resistance due to the slip stream of the airscrew; also that the motor requires no external cooling. In order to accommodate the engine and crew we will consider that the biggest cross-section of the body is 12 square feet approximately round in section. The resistance of such a body will be about 2 pounds to the square foot at 100 feet a second forward, *i. e.*, 24 pounds in all.

The resistance of the rest of the aeroplane by careful design can be kept down to 16 pounds at 100 feet a second: consequently at that speed the total resistance other than the wings will be 40 pounds.

The area of the wings necessary will be governed by the speed at which it is considered reasonable to land; taking 60 m.p.h. as a possible speed and assuming that the planes can be converted into a deeply cambered section for landing, the permissible loading of the aeroplane will be 15 pounds per square foot, making a total surface of 200 square feet.

We will now take a speed of 350 feet a second, or 240 m.p.h., and find the horsepower required at a height of 10,000 feet, *i. e.*, where the density of the air is 0.74 of the normal. The wing drag may be taken as a fifteenth of the weight as with wings of varying camber we shall be able to get a high lift-drag ratio even at a small lift coefficient. The resistance due to wing drag, therefore, will be 3,000/15, which is 200 pounds.

As the aeroplane is flying at 350 feet a second, the body drag will be 3.50 times what it was at 100 feet a second, which will be 490 pounds. As, however, the air is 26 per cent. less dense, its resistance will be reduced to 364 pounds.

The total drag will be the sum of the body drag and the wing drag, 564 pounds in all. Taking an airscrew efficiency of 85 per cent. on the power required for flying will be very nearly 430, which is just the power available.

The example just taken may seem fantastic to many people here tonight; it must be remembered, however, that when the Wright Bros. were flying at 40 m.p.h. speeds of 150 may have seemed to them equally fantastic. On the assumptions we have made it is reasonably certain that a speed of four miles per minute can be obtained, and as motors of less weight per horsepower become available there is no reason why this speed should not be exceeded.

The rate of progress in increase in speed will depend upon the demand for speed. If war were to last it is almost certain that speeds of much more than 200 m.p.h. would be common in quite a few years from now.

In the original Wright aeroplanes no attempt was made to obtain stability. The aeroplane was definitely unstable and required considerable care on the part of the pilot to keep it in equilibrium.

The early French aeroplanes were a little better in this respect, but the first aeroplane to prove that it really was stable, *i. e.*, it could fly without control, was that designed by Lieut. Dunn. This was an aeroplane of somewhat curious construction and never became a success, although it certainly was stable; on a windy day it was somewhat difficult to persuade it to fly on a straight course and its control when landing seems to have been insufficient. Lieut. Dunn, however, certainly showed that a completely stable aeroplane was a possibility.

About the time at which Dunn was making his experiments certain German designers claimed that they had produced a stable aeroplane. No records seem to exist of any test that proved their aeroplanes were stable, and in any case they certainly suffered from lack of control.

The first aeroplane of normal type that was proved to be stable was produced as the result of experiments carried out by the late Edward Busk. An aeroplane known as the R.E.-1 was used for the first experiments and it was modified until it was made completely stable. Tests were carried out in order to prove that this aeroplane really was stable, and with Busk as pilot, carrying Colonel Sykes as observer, a flight was made from Farnborough to Salisbury Plain, in which the only control used was the rudder, and this for part of the time at least was worked by Colonel Sykes.

Since that day most English aeroplanes have been designed to be stable; it has been found that for purposes of fighting an aeroplane that is extremely controllable is necessary, and it has been also found that if an aeroplane is made too stable the controls are apt to become too heavy to make the aeroplane sufficiently sensitive. In modern-day aeroplanes intended for war purposes the aim of most designers is to make the machine just comfortably stable over the range of speeds used in ordinary flight, but to provide sufficiently large controls that the inherent stability of the aeroplane can be entirely overcome.

It is often asked, if we have stable aeroplanes why do we still have flying accidents? It would be quite possible to design an aeroplane in such a way that whatever the pilot did with the controls he would be unable to upset the equilibrium of the aeroplane. Such an aeroplane, however, would be valueless for fighting, and as practically all aeroplanes nowadays are made for war purposes there must continue to be an element of danger for the unskilled pilot.

Increase in speed and the increase in controllability both tend to increase the stress that will be put on the structure of an aeroplane in flight. Experiments in the increased loads that are likely to occur when doing sharply banked turns and loops have shown that the load is frequently increased to three or four times the normal.

Present-day aeroplanes have to be very much stronger than before. Modern machines that are expected to maneuver rapidly are not considered tolerably safe unless the wings can support at least six times the weight of the aeroplane. Fortunately, large aeroplanes for peaceful purposes will not be required to maneuver very rapidly. This fact will have an important bearing on future possibilities.

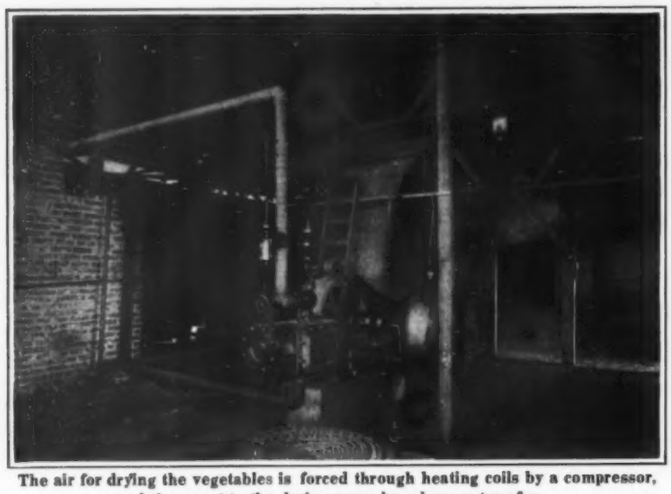
In an earlier paragraph it was stated that the proportional weight of the aeroplane parts proper was more or less constant. This applied only to machines of the sizes that are used now, *i. e.*, up to about 6 tons loaded weight. As aeroplanes are made bigger, if they are designed on similar lines, the weight of the wing structure per square foot will increase, assuming they are to be designed for the same factor of safety. It is true that on the large aeroplanes now made this increase of weight is not very apparent because greater trouble is taken to economize in the design of the wings. This increase of weight, however, is likely to be important for machines of much larger size, but as we shall be able to use somewhat lower factors of safety the weight of the wing structure will not increase as rapidly as it would otherwise have done.

We have no logical right to think that our flying machines of to-day are more than the crudest caricatures of the aeroplanes of the future. We engineers are a little apt to become so engrossed in our immediate difficulties of design that we do not see further ahead than is suggested by our own ideas, and make predictions for the future that only follow along the lines of progress that we can clearly see.

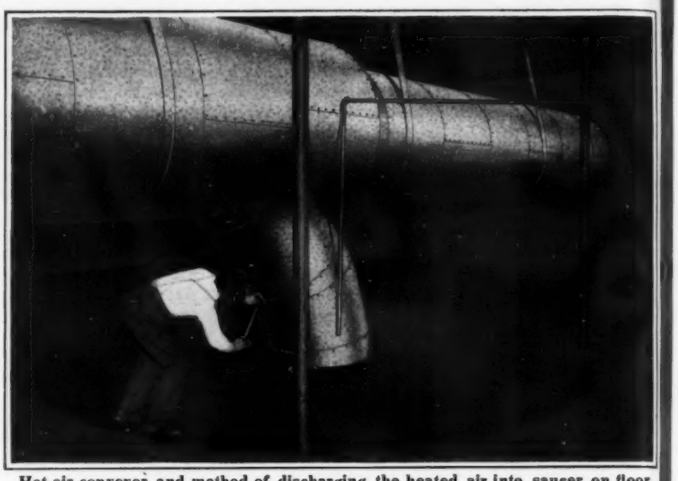
The writer has often been asked if he thinks that flying will ever become an ordinary means of travel. His answer is that he does not think, but that he knows it will become so. Ten years ago to attempt to fly from place to place was considered suicide; five years ago it was an adventure; to-day to many of us it is a very ordinary affair. A few years more and we shall laugh to think of the aeroplanes of which we are now so proud, we shall shudder at the risks we ran, and we shall travel with comfort, speed and safety.

Mosquitoes and Swamp Fever at Paris

According to *Le Matin*, it appears that the presence of soldiers in Paris who had returned with swamp fever from Oriental countries led scientists to fear that there might be some danger to the population. In fact the mosquito here resembles the Oriental mosquito which is active in transmitting this malady, and Dr. Roubaud found that these insects collected from around Paris became, in fact, in a contagious state after having come in contact with the fever patients. It is certain that they are able to convey the malady, and for this reason the Paris medical authorities, and especially Prof. Laveran, are taking all the necessary measures to isolate the patients and to place them apart in districts where there are but few mosquitoes. These questions came up during the last summer, and it is claimed that all due precautions have been taken so as to avoid danger from this source.



The air for drying the vegetables is forced through heating coils by a compressor, and then sent to the drying room by a large rotary fan



Hot-air conveyor and method of discharging the heated air into saucer on floor of the drying room to secure equal distribution

Drying Vegetables a New Conservation Move

The Process Greatly Extends the Farmers Market

By Arthur L. Dahl

WAR is the best teacher of conservation the world has ever known. At such a time all forces unite to conserve food supplies and new ways of utilizing and saving fruits and vegetables are devised. Often, too, some of the "lost arts" are resurrected and restored to practice.

One of these neglected arts is that of drying vegetables to insure their keeping qualities almost indefinitely. The process is simple, requires no complicated machinery, and has been practiced abroad for a great many years. In this country, however, the drying of vegetables has received but slight attention, but since the advent of the United States into the war some public-spirited Californians are endeavoring to introduce the custom, and one of the largest producers of vegetables in this country is devoting the great resources of his numerous plants to the commercial drying of all kinds of vegetables and berries, not so much with the idea of making money from the needs of the world's consumers, but for the purpose of aiding in the conservation of our food supply.

From 80 to 98 per cent. of all vegetables and fruit is water, and a tremendous saving can be effected in their handling, transportation and marketing if a large proportion of these food products are dried before being sent from State to State or to foreign countries.

The mere saving by drying the vegetables now lost through being undersized, imperfect and unsuited for shipment would feed the entire people of Belgium. From 20 to 40 per cent. of all perishable crops are wasted or rendered unfit for consumption, in their fresh state, before they reach the consumer, and a large share of this waste could be saved by drying the vegetables at the places where they are raised.

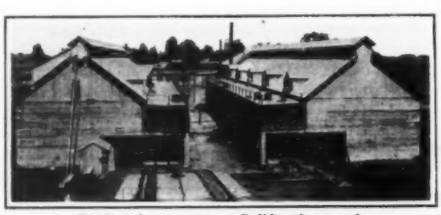
From the standpoint of transportation, too, an enormous saving would accrue from the process. In the shipment of canned tomatoes, for instance, 98 per cent. of the gross weight is water. Where both rail and water tonnage is at a premium, the utilization of shipping facilities for such a large proportion of watered stock is certainly not efficient, if the same food supplies, in a dried state, would be approximately as good, and chemists assure us they are. Again, the wastefulness of labor, tin, lumber, storage and handling expense and deterioration in the fresh or canned vegetables, as against the smaller bulk and keeping qualities of the dried products, is apparent.

One hundred pounds of fresh vegetables when dried is reduced to from five to eight pounds, and no expensive containers are needed for the product. In the case of potatoes, it is estimated that more than 20 per cent. of the entire crop is left unpicked as culls, or lost en route to the consumer. Another considerable loss is sustained in peeling them by hand. In machine peeling there is practically no loss, as the peelings are saved and treated for their starch content. When dried on the ground it is possible to utilize the sound portions of all imperfect vegetables or fruit as well as the culls.

When we consider that such dried fruits and vegetables as prunes, peaches, apricots, apples, raisins, figs, mushrooms, onions and many others have been used in almost every family for years, it seems strange that the process has not been extended to many other members of the vegetable family. The great abundance of all kinds of food supplies in this country and our wasteful practices have prevented the industry from getting a firm start here, although in some parts of the country, notably in the Northwest during the great Alaska mining boom, large quantities of dried vegetables were, at different times, displayed in all grocery stores and met with ready sale.

The British Government, known for its conservatism, used dried vegetables extensively during the Boer War of 20 years ago, and some of the supplies left over from that war have been used to feed the soldiers in the present conflict. England now buys from Canada millions of pounds of dried potatoes, carrots, turnips, cabbages and other crops. The French and Italian governments have done likewise, while the German Government is said to have laid up vast stores of dried vegetables in preparation for this war.

In European countries the universal drying of food products is almost obligatory. The surplus vegetables in the city markets are forced, by the governments, into large municipal drying plants. Community driers are established in the trucking regions and even itinerant drying machines are sent from farm to farm, drying the vegetables which otherwise would go to waste.



Drying house on a California ranch

It is well known that a large proportion of the perishable fruits and vegetables produced in this country is wasted. They must be handled quickly, and unless transportation facilities are excellent, many of the products of the farm are too far from a market, other than the canning establishments, and the contract of the average cannery is not particularly favorable to the grower, and only perfect specimens are accepted. With the establishment of commercial drying plants, or even the installation of small plants on each farm, enough food could be saved each season to feed all the starving peoples of the world.

California and Oregon have, for years, produced a large part of the world's crop of hops. The hops from this section of our country are of such excellent quality that buyers come from even the hop districts of Austria to purchase supplies. The hops, when picked, are more or less green, and contain a large volume of moisture, which is extracted in plants especially designed to dry them. One large hop operator in California controls thousands of acres, and the company has plants for handling this product stretching from Canada to Central California. Other agricultural crops, beside hops, are raised on these lands, and in observing the great waste incident to the handling of perishable supplies, even under most modern conditions and by efficient methods, the idea was conceived of utilizing the many drying plants controlled by the company for the drying of vegetables and berries raised in the neighborhood.

The hop curing season lasts but a few weeks out of each year, and for the remainder of the season the machinery is idle. The same principal is used in the drying of hops as in the drying of other vegetables, and from an economic standpoint, one central drying plant in a community could take care of the products of all the farmers. In the early spring the berries could be processed, and as the season advanced and new vegetables came into production, new varieties could be added, thus keeping the operating force busy throughout the season and reducing the overhead charge to a minimum.

To determine whether or not different kinds of fruits and vegetables could be dried in the hop houses, experiments were conducted with almost every variety of fruit and vegetable raised in the vicinity and the result was beyond expectation. The dried product, when compressed into small cubes, or placed in sanitary cartons, occupied but a fraction of the space required in its fresh state, and analysis made by chemists disclosed the fact that the food retained practically all of its original flavor and chemical constituents. In fact, according to experts of the Department of Agriculture, water is all that is taken out; flavor, texture and food value are not impaired.

When the vegetables are dried as a whole, without being sliced or cut up, the mere soaking of the dried product in water will restore it, in an hour or so, to almost its natural size and dimensions. Sweet potatoes, for instance, that were dried, by being soaked in water were restored to their natural bulk and were suitable for frying. When served it was hard to tell them from the fresh variety. Some of the dried vegetables were tried by Mrs. Wilbur, the wife of the president of Stanford University, and she became enthusiastic about them, and reported that they retained the flavor of the fresh varieties.

The drying process is very simple. The vegetables are first thoroughly cleaned, and unless they are to be dried in the whole state they are sliced or shredded by hand or mechanical means. The product is then placed upon shallow trays and laid upon the floor of the drying room, where they are subjected to a constantly circulating current of warm air, kept at a temperature of from 110 to 150 degrees F. The time required for the processing of the various fruits and

vegetables varies according to the bulk and moisture content, and the temperature is maintained at a figure which will most rapidly absorb the moisture without producing a mold. The product is not allowed to get too dry, as the retention of a portion of its moisture is needed to insure the vegetable being restored to its natural shape when soaked in water. No preservative is added, and the entire process consists in extracting the moisture and leaving only the chemical constituents and bulk remaining.

In the commercial hop-drying plants, used for the experiments, the heat is applied to the drying room by having the air pass through a heated coil, after which it is forced, by a powerful fan, through a large pipe which descends from the ceiling or sides of the drying room to within a few inches of the floor. The air from this pipe is forced against a round saucer-like bowl which causes it to be thrown out into the room under a uniform pressure, and a constant circulation is thus maintained throughout every portion of the room. Under many of the other drying systems, it is difficult to maintain an even temperature in every portion of the room, but the rounded saucer produces this result.

The use of dried vegetables as even a part ration for our army would result in a tremendous saving in freight. One carload of the dried product is equal, in food value, to a hundred of the fresh or canned variety, and in this day of inadequate tonnage, the saving to be accomplished in our exports would be enormous. That the dried product would be quite as palatable as the fresh is not to be expected, but that it contains the same food values as the fresh cannot be denied. But if the normal difficulties of feeding the vast armies engaged in the world war can be lightened by the use of this new form of concentrated food a great deal of good will have been accomplished. In Alaska to-day and in those parts of the world where a man wants to travel light and yet take with him the maximum amount of food we find the plentiful use of dried vegetables.

Just as the average farmer has his smoke house for curing the hams and bacon needed for the use of his family, so, in the days to come, it is possible that every farm will have installed the simple facilities needed for drying the surplus vegetables raised on the farm. As the entire principle of vegetable drying involves merely the extraction of the moisture content, the task is simple and the equipment needed can be easily supplied. In midsummer the long, sunny days will serve, and a wire cage receptacle erected over the kitchen stove will do the work as successfully as the most modern commercial plant. And the duty to save food is as great as the duty to produce it.

The difference between evaporated and dehydrated products is marked. Evaporation is usually done at temperatures high enough to convert fruit and vegetable sugar into caramel, giving an objectionable flavor, whereas dehydration is done by gentle heat, leaving the sugars intact. The French have known and used for years what are known as Julienne vegetables, prepared by dehydration, while Germany had more than 400 dehydrating plants at the outbreak of the war and is now credited with 2,000. In dehydration fruits and vegetables are first pared and sliced and then subjected to a gentle pulsating current of heated air. This air carries off the moisture sweated out of the product and is dried with washed fresh air and recirculated. Dehydration offers remarkable possibilities for the preparation and marketing of perishable foods. These products occupy from 50 to 80 per cent. less space than fresh fruits and vegetables and weigh from 60 to 90 per cent. less and are reasonably imperishable. They eliminate waste by decay, reduce transportation and storage costs, and are ready for cooking with minimum labor. Dehydrating does not impair the form, quality, flavor or nutritive value of food. It is difficult to distinguish the prepared product from the fresh when cooked, and in many cases where tender varieties of fruit and vegetables are dehydrated in the country, shortly after gathering, there is a marked superiority in flavor over the sturdier varieties shipped fresh long distances to city markets.

Our Sun and Other Sky-Furnaces

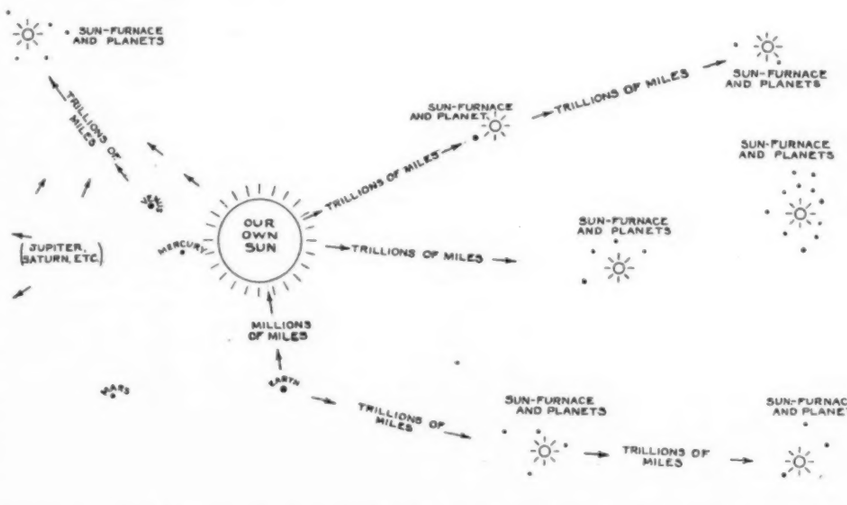
By Charles Never Holmes

ACCORDING to very modern astronomical research the sun which lights our little planet-home also warms it with an amount of heat—provided the sun is shining directly overhead—sufficient to melt within an hour a sheet of ice 7/10ths of an inch in thickness. Therefore, in the course of a year, our earth would receive from the sun enough heat to melt a shell of ice wholly covering this planet to the depth of 124 feet, that is, if the heat were equally distributed everywhere. From these facts it is evident that Sol is a regular sky-furnace, warming not only our own earth, but also all the other planets and satellites. Of the total solar heat radiated out into the ether of the universe a vast amount is, as far as we know, lost—although it may be that this so-called "lost" heat is returned somehow to its source—and, indeed, our planet-home is warmed by only 1/2,200,000,000th of the sunlight poured out into the space surrounding us and the rest of our solar system.

It must be a fact, then, that our sun is a *very* hot furnace. Now, the popular thermometer by which we take temperature—the thermometer that hangs outside our windows—is known as the "Fahrenheit," and, according to this Fahrenheit scale, the temperature at the sun's surface has been estimated to approximate 9,000 degrees. Most of us think that 100 degrees "in the shade" indicate a pretty hot day! But the scientific thermometer is called the "Centigrade" and the intense heat at the solar surface approximates, when changed from the Fahrenheit scale, 5,000 degrees, C. Of course this "effective temperature" has been variously estimated, and one of the latest computations places it about 5,500 degrees, C. Nevertheless, whether the real solar temperature is 5,500 degrees, C., or even higher, Sol is certainly a very hot sky-furnace, hot enough to melt at his surface each minute a shell of ice many feet in thickness. This solar temperature of about 5,500 degrees should be compared with that of the most intense electric arc—about 4,000 degrees.

Of course our sun is only one of a multi-myriad of such suns, some of these suns being much larger than our own sky-furnace. Since each of these other stars has in all probability a solar system of planets and satellites, each is a sky-furnace which warms more or less noticeably the planetary members of its own system. The heat of these suns of night varies according to their respective ages and sizes, like a large piece of burning coal throws out more heat than a small piece and coal fully ignited is hotter than when it begins to burn or is about burned out. And not only do these other stars warm their own solar systems but they must radiate heat to our very remote planet-home, although the amount of heat which we receive from any one of them is utterly insignificant and almost wholly imperceptible. The heat from these far-away suns can, however, in the case of some of them be approximately measured.

Astronomers are able to compute roughly the temperatures of a few of these sky-furnaces. The sun Gamma in the constellation of Cassiopeia is estimated to have a temperature of 50,000 degrees, C., while Sirius and Vega, very brilliant suns respectively of our winter and summer firmaments, have approximate temperatures of 27,000 and 18,000 degrees, C. On the other hand, such stars as Capella and Arcturus, also very bright suns of our winter and summer evenings,



possess temperatures less intense than that of our own sun. We all of us have seen or heard about the north star, called Polaris—it is easily found in the darkened heavens—and this north star is a sky-furnace with a temperature approximating 7,000 degrees, C.

So that when we see the sun to-day or the suns to-night we should not think of it or them as merely ornamental, scintillating gems of our darkened dome, but as useful members of the universe—sky-furnaces that are developing and preserving by their warmth the various animal and vegetable lives upon their respective planets and satellites.

Treatment of War Wounds

NEW methods for treating war wounds were the subject of a paper presented to the Académie des Sciences by Dr. Benoit. He combines the effect of the sun's rays with that of ultro-violet rays, and in this way he obtainins excellent results in the treatment of wounds.

Are Concrete Ships Desirable

A LARGE amount of matter has been published of late in regard to the building of ships of reinforced concrete, and, indeed, the plan has been received with such enthusiasm, as a method of rapid production, that it is reported that our Government has given out contracts for the building of a number of such vessels. It is true that several successful boats of small size have been built, but when it comes to large sea-going vessels we are largely in the dark.

Many well-qualified technical and scientific men consider the claims made for the concrete ship are entirely too optimistic, and at present unjustified; and the February issue of International Marine Engineering contains an illuminating article on The Fallacy of Concrete Ships by Professor H. A. Everett, of the U. S. Naval Academy, that discusses the subject from the point of view of an expert. Among other things commented on in this article is the fact that the effects of sea water on reinforced concrete structures is by no means well understood, and even on land, where conditions are by no means as complicated, new and serious problems are constantly arising. A particularly important point is that the principal stresses which the seagoing hull structure must withstand are tensional which is the sort of stress that reinforced concrete is least suited to withstand.

It is further pointed out that the tensile strength of reinforced concrete is that due to the steel in it, and that for equal size vessels there must be as much steel in the strength members of the concrete ship as the steel ship, and the concrete becomes so much additional weight which must be paid for in reduction of weight elsewhere, or in reduced carrying capacity. Moreover, it must be remembered that there is no such thing, at present, as a concrete that is not permeable by water, and that as soon as brine comes in contact with the reinforcing rods deterioration commences.

A number of other features are discussed, but enough have been mentioned to indicate that this form of construction, as applied to ships, presents many new and undetermined problems that will seriously test the engineers. It is reported that a large vessel of reinforced concrete has recently been launched on the Pacific coast, and the results of the experiment will be awaited with interest.

ONE of the principal industrial problems in France is the production of alcohol in sufficient quantity for war and other uses. It is considered that distillation of fruits will solve the problem to a great extent.

Modern Margarine Technology*

An Outline of Its History and Manufacture

By W. Clayton, M.SC.

THE introduction of new and extensively used foodstuffs has often synchronized with periods of great wars. Thus condensed milk was first used in large quantities by the Northern Armies in the American Civil War, in 1856, and soya-beans and bean oil were developed as a result of the Russo-Japanese War, when the Japanese soldiers found soya-bean products a staple war-food. Margarine is pre-eminently a war product, having its inception during the Franco-Prussian War, and finding its place as a universal article of diet during the present great struggle.

Margarine manufacture is really a present-day success, with a seemingly prosperous future ahead. It is cheap, made from quite pure materials, having excellent food values, and simulates butter very closely. The former prejudice against its use is rapidly breaking down, and to-day the industry is very promising indeed, and many new works are being established, pointing to keen competition after the war.

When, in 1869, the French Government offered a prize for a cheap butter-substitute, to conform as closely as possible in physical and chemical characteristics with butter, and of good keeping qualities, a French chemist, Mège-Mouriès, began a research into the formation of fat in milk. He reasoned that in the animal metabolism, the carbohydrates are converted into fat, which in turn changes into butter-fat by the process of pepsin-digestion. This led him to try to effect artificially a similar change in animal fats. Fresh beef fat, usually from the kidney or intestines, free from tissue, was digested for two hours at 45 degrees C. in an aqueous solution of sodium carbonate, in presence of pigs' or sheep's stomachs. As a result of pepsin action, the fat was completely separated from the remaining tissue; it was then skimmed off, and warmed with a 2 per cent. solution of common salt to prevent early rancidity. On standing, a yellow fat separated which was cooled to about 22 degrees C. The semi-solid mas possessed a butter odor, and when pressed between warmed plates, the more fluid constituent was obtained, averaging about 50 to 60 per cent. of the fat. This fat, when cooled, had a butter-like consistency, and was termed "Oleomargarine," being sold as such in Paris.

Mège-Mouriès improved on this product by churning it with 10 per cent. of cow's milk, and water containing macerated cow's udder (0.4 per cent), until a satisfactory emulsion was obtained. This was solidified, washed, salted, colored and sold as a butter-substitute, having a moisture-content of about 12.5 per cent. and a m. pt. of 17-20 degrees C.

Factories were erected and developed in Austria, and later, in 1873, an English patent was taken out by Hippolyte Mège. The Parisian Council of Hygiene, in 1873, sanctioned the sale of these butter substitutes, at the same time prohibiting their claim to the title "butter."

The name "Margarine," derived from the Greek word for "pearl," was introduced by Chevreul, who applied it to the compound formed by the union of margaric acid and glycerin, as found in human fat and in olive oil. It is not certain whether "margarine," as thus understood, is a definite chemical compound, for whilst some chemists regard $C_{17}H_{34}O_2$ as margaric acid, a definite member of the stearic series of fatty acids, others claim it to be merely an eutectic mixture of stearic and palmitic acids.

Adopting Chevreul's nomenclature, the oleomargarine described above was thus considered to be a mixture of olein and margarine, the stearine matter having been removed.

Since the time of Mège-Mouriès, the manufacture of margarine has steadily progressed, numerous oils have been introduced, and up-to-date methods and machinery brought into vogue. The fat is no longer digested artificially, the flavor of butter being simulated in other ways. Also margarines from vegetable oils and fats have steadily displaced the former purely animal products.

The chief animal fats employed in margarine manufacture are lard, oleo, "premier jus," and stearine. "Premier jus," obtained from the best beef fat, can be fractionated to yield oleo and stearine, *e.g.*, by hydraulic pressure at 48 degrees C., using filter-cloths, or by fractional crystallization for some days at 28 degrees C. By the former method, the more fluid oleo oil is expressed; in the latter, the harder stearine crystallizes out.

Stearine is not used in large proportions in a margarine mixing because of its high melting point (54 degrees C.), but is useful when vegetable oils preponderate, as it corrects the consistency of the final product. The corresponding mutton oleo, jus, and stearine are not in such demand, and their physical properties are somewhat different from their beef analogues, thus leading to changes in the composition of the margarine. A great variety of vegetable oils is employed. The solids or fats include cocoanut and palm-kernel oils, and in the United States palm oil is also used. The oils include cottonseed, arachis, soya-bean and sesamé oils, and more recently kapok, maize and wheat oils. Last, but by no means least, must be included hardened or hydrogenated oil, which will be discussed in some detail later.

The refining of oils for edible purposes has become a fine art, and almost any of the vegetable oils just mentioned can be obtained quite tasteless and odorless, and of a high analytical degree of purity.

Upon the relative proportions of these various oils and fats, both animal and vegetable, depend the quality and texture of a margarine. It may be taken for granted that where much animal fat is used, a dearer brand of margarine results, and that the cheapest brands are almost entirely vegetable in origin. The formulæ or compositions employed depend upon the quality required, the market condition prevailing, and the weather. In warmer weather, more of the solid constituents will be used.

The introduction of hydrogenated products in margarine manufacture marks a great technical advance, and one which is likely to develop very rapidly in the future. The fundamental principle underlying the hydrogenation of oils and fats is to make valuable hard fats from relatively cheap raw material, by the addition of hydrogen. By the addition of about 1 per cent. of hydrogen to cottonseed oil, for instance, a fatty product of at least the consistency of lard may be obtained. Since hydrogenation can be stopped at any time, it is obvious that with a given oil, an end product of any desired melting point up to that of the fully saturated product is possible. Hydrogenated oils have excellent keeping qualities and are said to help margarine in this respect. Knapp found no rancidity in samples of such oils even after 18 months, and the free acid content (0.7 per cent. as oleic acid) remained practically constant. An objection has been raised by Brauner that hardened oils raise the moisture content of a margarine, owing to their property of retaining water, much in excess of what other oils do. He claims to have proved this on a large scale on many occasions. As far as I am aware such a difficulty has not been met with in our factories, and in any case, the problem admits of very easy solution.

The use of hardened oils really hinges upon their edibility or otherwise, and on this point much controversy has raged. Little doubt exists as to their being thoroughly suitable for human consumption, since they are assimilated during human metabolism just the same as any other fats, but whether the traces of metal catalyst almost invariably present affect the health, was for a long time a dubious matter.

Nickel is the most widely used catalyst and traces of it are to be found in most samples of hardened oils. The amount of this metal likely to be present depends on the amount of free acid in the oil, and on the time of actual contact of oil and catalyst. Bömer found in a sample of hydrogenated sesamé oil containing 2.5 per cent. fatty acid, an ash content of 0.01 per cent. with 0.006 per cent. of NiO. Again, a whale oil with 0.6 per cent. fatty acid had an ash of 0.006 per cent. with 0.0045 per cent. NiO. Thus if a daily quantity of 100 grms. of hardened oil were eaten, the maximum amount of nickel absorbed would be 0.6 mgrm. Physiological tests show this quantity to be quite harmless; in fact, it has been proved that small daily doses of nickel powder have no ill effect, 99.8 per cent. of the metal being rapidly excreted.

Another objection that has been raised against the use of these oils in margarine manufacture is that good products may be prepared from bad raw material. As a particular instance, whale oil can be hydrogenated to yield a tasteless, odorless and germ-free fat, physiologically harmless. Suspicion was aroused that margarine manufacturers might use cheap and unwholesome fish or other oils, hardened to form good clean products. Much controversy has centered round this point. So long as the raw material was unsound, the public would not sanction the final margarine. Maybe there will be a legal fixing of the raw material in the future. At any rate, such a course has been frequently advocated, especially in the United States.

Milk is used in margarine manufacture for two primary reasons, viz.: as a basis for flavoring development and as an emulsifying agent. Only milk of a high hygienic standard should be employed, either fresh-skimmed or separated. It is an ideal medium for micro-organisms, containing, as it does, the essentials of life in a readily assimilable form. The micro-organisms present in milk are lactic and butyric bacilli, various yeasts and moulds, and pathogenic organisms. For the destruction of the undesirable bacteria, especially of the pathogenic type, the milk is pasteurized by heating to 82 degrees C. for a few minutes. The chemical and physical properties of the milk were not considered to be seriously affected, until quite recently when Renshare and Ware showed that there is a rapid decrease in the amount of sugar, and an increase in acidity, on pasteurizing milk. The lactose is decomposed by certain lactic organisms which act very rapidly at 80-85 degrees C., producing lactic acid, part of which is probably transformed into other substances, since the acid found never exceeds one-third of the amount of lactose decomposed.

By heating to 82 degrees C. the milk is deprived of some useful souring bacteria, but also has its content of undesirable and pathogenic organisms reduced. A government report of 1914 by Delépine states that the bacterial content of 1 grm. of milk was reduced from 14,120,000 to 1,900 in one case and from 5,770,000 to 100 in another. Much discussion has taken place as to whether the tubercle bacillus in milk is killed during pasteurization. Richmond, in his work on "Dairy Chemistry," p. 282, says, "As the tubercle bacillus is comparatively easily destroyed by heat, pasteurization of milk may be resorted to to destroy the organisms; keeping the milk for 15 minutes at 70 degrees C. will practically remove the source of infection." Delépine states that he is convinced "that cream infected with human tubercle bacilli was not invariably sterilized when exposed to a temperature of 85 degrees C. even when the exposure lasted 15 minutes." He continues: "I subsequently obtained similar results with milk containing tubercle bacilli of bovine origin."

Unfortunately the complete sterilization of milk by boiling is prohibited, inasmuch as the characteristics of the milk would be too much changed, and a burnt flavor would result. It is very probable, however, that in the near future pasteurization will be replaced by complete electrical sterilization, a method which would leave the physical and chemical and flavoring characteristics of the milk unaltered and would be ideal from the margarine manufacturers' standpoint. Milk can be sterilized by means of a high tension alternating current, and such a method has been patented. It should also be possible to have a large scale ultra-violet ray apparatus to sterilize milk at ordinary room temperature, just as Dornac and Daire sterilized water using quartz electric lamps. Butter and fats have also been rendered germ-free, by being carried on an endless band or a revolving drum in a thin layer, past a series of ultra-violet ray lamps. In any case, the future holds much in store for changing this part of a margarine process involving the incipient reduction of all the bacteria in the milk.

In the present system of pasteurization, the milk is well agitated, and delivered, after being pasteurized, about 8 feet above the inlet level, thereby enabling a vertical cooler to chill the milk as it descends to the souring tanks. By cooling to about 10 degrees C. bacterial activity is inhibited and the action of germs which have resisted heating, or have gained accidental access, is minimized. It now becomes necessary to inoculate the milk with those germs necessary to develop

*Journal of the Soc. of Chem. Ind.

a butter-like flavor. A pure culture, or "starter," is added, consisting of lactic acid bacilli. The temperature is raised to a point known to be favorable to the bacterial development, and lactic fermentation proceeds until a degree of acidity is reached which causes rapid precipitation of curd. The milk is again cooled to a safe inhibiting temperature, at which it is maintained until required in churning.

Lactic fermentation gives the milk a pleasant acid taste and aroma, due to the production of lactic acid, among other products, but the true flavor of butter is lacking. Much research has yet to be done before margarine can be made having a distinct and recognizable odor and taste like butter. Some manufacturers add flavors of various kinds when blending the final margarine, but this is only a temporary expedient. The true flavor will be obtained when the requisite bacterial action on either milk or fat is discovered. Personally I foresee a time when milk as a flavoring basis will not be required. Research should be directed somewhat along the lines of Mège-Mouriès' ideas, towards a pre-digestion of the fats to butter-fat, or else to a selective bacterial action on both animal and vegetable fats. Water and an emulsifying agent could then replace milk. My own experience leads me to a quite optimistic view of probable progress in this direction.

The milk having been prepared for churning, it is now necessary to emulsify the oils with it. According to the quality of margarine desired, a mixture of animal and vegetable oils and fats is melted in large vessels, in which the temperature can be adjusted by means of steam or cold water. The melted mixture passes through strainers to a temper-room, where a constant suitable temperature can be maintained for each given mixture. This, however, is not really a necessary procedure; all temperature adjustments can be made just as well in the melting room, and then the oils are run straight to the churns.

Two types of churn are in general use. The older is a double-jacketed vessel which may be heated by steam, or cooled by water, as necessary, and is provided with stirrers, *e.g.*, two sets of revolving baffle-plates. The oil or milk is added, the other constituent is then run in. Sometimes both oils and milk flow in together. Efficient stirring at a suitable temperature is maintained, until emulsification is satisfactory. The emulsion is then released through a valve at the bottom of the churn, and flows onto a slanting shoot, where it is immediately met by a spray of ice-cold water, striking upon it with such force as not only to cause instant solidification, but also to break up the mass into yellow granules. These so-called "crystals" float down the shoot in the excess water, and collect in a wooden trough beneath, which permits complete drainage of the absorbed water.

The newer type of churn is electrically controlled, and is of the "continuous" type, *i.e.*, milk and oils are led by separate pipes to a thermo-regulated chamber, where on intermingling, numerous blades, rapidly revolved by means of a motor, effect complete emulsification, the emulsion being discharged as soon as formed, onto a shoot as already described. Alterable pumps allow regulation of the flow of milk and oils, so that various mixtures may be employed, according as one quality or another is desired. This electric or continuous churn is coming into great favor, and is far in advance of the older type.

In some factories the ice-water spray is not employed. Instead, the emulsion is solidified on a well-cooled revolving drum, and the solid margarine stripped off automatically.

The process of emulsification is of first importance. The object of churning is to imitate the emulsion found in cream and milk, where the fat globules have diameters ranging from 0.01 mm. to 0.0016 mm. and remain as discrete particles. The general theory of emulsification indicates that with two immiscible or only partially miscible liquids, two types of emulsions are possible, each constituent being in turn the disperse and then the continuous phase. For concentrated emulsions a third agent is required. Where oil is to be the internal of disperse phase, the emulsifying agent should be capable of lowering the surface tension of the external or continuous medium, and should be viscous, as is glycerin, or an emulsoid, like gelatin. If oil be dispersed in water, a stable emulsion can be made, the stability depending on the minuteness of the oil drops, this in turn being a result of the efficiency of the emulsifying apparatus. If, however, water be dispersed in oil, a very unstable system is produced, separation into two layers taking place as soon as beating up ceases. Now milk, by virtue of its colloidal content, is an excellent emulsifying agent, when oil is the disperse phase. Consequently if milk be in a churn in bulk, and oil is slowly fed in, with continuous agitation, an excellent emulsion of great oil concentration can be produced, and will set to a homogeneous mass afterwards. But if, as in some factories, oil be in the churns in bulk, and milk is fed in, a very unstable system results, which easily separates into layers on stopping the agitation for a while. This has been proved many times, and the explanation seems clear. To get a suitable emulsion of water in oil, one would require an emulsifying agent which should form an *oil*-soluble colloidal solution, but in milk the colloids are *water*-soluble. Both theory and practice condemn any form of churning which would lead to emulsions with oil as the continuous medium. Such emulsions when cooled by ice water, or on drums, solidify with clot formation, and the resultant margarines are "spotted" in texture. It is interesting to note that the electric continuous churn gives a stable emulsion of oil in milk, as would be expected from theoretical principles.

The temperature of churning is very important, and, other things being equal, about 25 degrees to 35 degrees C. should be the rule. Higher temperatures lead to milk curdling, and consequent spotting of the finished margarine by casein clots. Also one must remember the very delicate relationship between flavor and temperature.

Though some technologists still maintain that fats of high-melting point like stearine lead to imperfect emulsification, and consequent poor texture in the final margarine, it is possible to work under such conditions as to obtain eminently satisfactory emulsions. Conditions are known which allow even fairly large quantities of stearine to be mixed with low-melting vegetable oils, and yet give homogeneous and permanent emulsions.

Investigations have been made to increase artificially the efficiency of emulsification by the addition of various colloids to the milk. Starch, gelatin, glycerin, egg-yolk, lecithin compositions and numerous patent mixtures have been tried. These substances have been regarded as forming a membrane or film around the oil globules and so preventing their coalescence, thus leading to increased stability of the emulsion system. At the same time, it must not be forgotten that the electric charge on the particles may also play a large part in preventing coalescence. Still, whatever the ultimate explanation, it is a fact amply proved by experience that the addition of so small a quantity as 0.1 per cent. of, say, glycerin or gelatin to the milk before churning, leads to much better emulsification. Where the ice-water spray system is used, the starch, gelatin or other reagent is washed out, and cannot be detected in the final margarine. This is a decided advantage from the manufacturer's point of view. The rapid cooling and crystallization of the emulsion inhibits separation, and also serves to absorb the minute casein particles associated with the fat globules.

The yellow "crystals" are removed to a maturing-room, where, under constant thermal conditions, the bacteria introduced by the milk can develop. This occupies many hours, depending upon the quality of the margarine being made. The best animal margarines are permitted the longest maturing time. Maturing accomplished, it is now necessary to knead the "crystals" together to form a coherent, butter-like mass, and at the same time to expel the excess of water, since the legal limit of moisture in margarine is 16 per cent. Consequently the matured "crystals" are rolled in drums, or passed between a set of rollers.

The average amount of water in the crystals is 33 per cent., and in the rolled product, 14.5 per cent.

The buttery mass is now passed on to the blending department, where it is prepared for delivery to the consumer. The b'enders hold various amounts of margarine and are fitted with curved blades, which by rapid revolution ensure thorough mixing of the margarine with salt, coloring matter, preservative, etc., in about 35 seconds. The amount of salt and color to be added is determined by the consumer. The quantity of butter added, as a means of ensuring nicer flavor and better texture, must not exceed the legal limit of 10 per cent. Preservative, usually boric acid, is added in amount not exceeding 0.5 per cent. This provides against undue bacterial action, whereby acidity would develop, and cause rancidity.

When the margarine has been blended, it is packed, labelled and passed into the cold storage until required for shipment.

In order to improve the texture of a margarine, the addition of 0.5 to 5 per cent. of a wax such as ceresin wax has been suggested. Glycerin has been used in this connection to impart a glossy appearance to the margarine. Glucose has been used, but Zoffmann has showed it to be injurious, owing to yeast fermentation leading to formation of carbon dioxide and bursting of the packages. Personally I see no need for the addition of anything in the blending of a margarine in order to improve texture. If the process of emulsification is controlled properly, and the right conditions observed for even those cases where stearine and other high-melting fats are used, the texture will take care of itself.

Analytically, the difference between butter and a margarine is soon found by a determination of the soluble and insoluble volatile fatty acids, the so-called Reichert-Meissl and Polenske numbers. But it has been urged that for a rapid and easy differentiation, some chemical reagent be added to a margarine. Thus Soxhlet suggested the use of phenolphthalein. In some countries, it is fixed by law that sesamé oil to the extent of 10 per cent. be a constituent of margarine, this oil permitting of a rapid and distinct color test.

Frothing and browning being characteristics of butter on heating, and margarine simply spluttering and separating into water and oil on similar treatment, it is usual when blending, to introduce some substance which will bring about frothing and browning, when even low quality or pastry margarines are heated. Amongst the many things proposed and in use are butter, milk powder, casein, lecithin, yeast, malt-extract, cholesterol, egg-yolk, lactic acid and many patent emulsions of lecithin and sesamé oil.

The advent of artificial milk is a distinct advance in margarine technology, and one likely to have far-reaching consequences. It is fairly easy to imitate milk in so far as it is an emulsion of oil in water; it is just as easy to go a step further and add lactose and mineral matter to the emulsion, to strengthen the similarity. But to imitate milk successfully, the casein constituent must be introduced, and this proved the stumbling block for many years, in all attempts to produce a synthetic milk. However, casein-bodies have been extracted from nuts and nut-meals by means of alkaline media such as phosphates and carbonates, and artificial milks have been made from which cream, margarine and cheese have been successfully produced. Here then is a new field, comparable with the introduction of hardened oils.

For the margarine manufacturer, having the oils, and possibly the oil-cakes, too, at his command, may produce milk artificially, pasteurize it, and then flavor it by means of a culture, and so be quite independent of the dairy-farms.

The margarine industry is new, but in its short life many advances have been made. There is no doubt at all but that the industry will prosper, and as its scientific principles become more and more exploited, and its technology more developed, the place of margarine as a permanent and staple article of food will be more and more recognized.

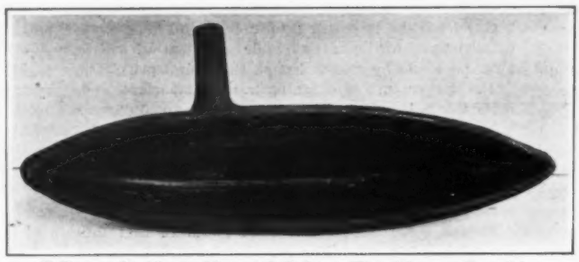
Indian Sumach

Sumach is an important vegetable tanning material used in producing the finer qualities of leather and similar in character to myrabolans, says the London *Chamber of Commerce Journal*. There are three kinds of sumach, the Sicilian, American and Venetian. The last-named is practically the same as the Indian sumach, being produced from the same tree. An unlimited supply of Indian sumach exists in the lower Himalayas, and if desired, large tracts of useless country could soon be covered with it, only the initial planting of the bushes being necessary. A bulletin of the Forest Research Institute of the Government of India has lately been issued with the object of bringing this tanning material to the notice of Indian tanners. Sumach is not so capable of such extensive application as babul bark, but is an important auxiliary of tan, which by admixture, improves the properties of other tans. The first crop of sumach leaves is secured during the year following that of planting. In India the leaves are collected from the middle of September to the end of October, according to the locality and the time of the ripening and the shedding of the leaves. After the second year, the crops obtained are superior in quality and more abundant. Spring and summer samples of Indian sumach leaves from different localities were found to contain from 6 to 13 per cent of tannin, while the autumn samples gave 18 to 22 per cent, and in one case as much as 26 per cent. Calculated on the dry material, the spring and summer samples gave from 7 to 14 per cent and the autumn samples from 21 to 26 per cent, the maximun being 31 per cent. In winter the percentage falls off. The color deepens toward the end of autumn. If a light color is required, the leaves should be collected in summer, though they will contain only half the percentage of tannin. This tanning material will no doubt become of increasing importance in view of the extension of the tanning industry in India which has taken place during the war.

The sundial is still seen as a decoration on country estates

"Water clock" showing leak hole

A portable sundial



Tallow melter for making rush-lights. The piths are dipped in molten wax

The sundial in various forms has existed from very early times

The Evolution of Time-Marking Devices

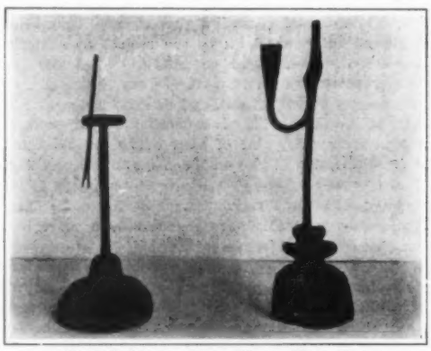
Some Simple Devices That Served Our Ancestors

By Percy Collins

THE progressive development of many human contrivances and inventions can be shown to have followed an almost straight course from the most simple to the most complex and efficient. This, however, is not the case with the evolution of time-marking devices; for, at different stages in his history, mankind appears to have adopted several expedients for registering the passage of time, and to have brought each of these to a more or less high level of perfection. What was the original time-marking device must necessarily remain a subject of conjecture. But as the activities of primitive man must have been largely regulated by the familiar sequence of day and night, the rising and setting of the sun would, with the first awakening of a conceptional faculty, become events likely to excite anticipation and remark. And one cannot doubt that the movements of shadows, obviously controlled by the transit of the sun across the zenith, were noted by man from a very remote period, and rightly interpreted by him as visible signs of time's passage. Thus, we may probably assume that the first time-marking invention—the forerunner of our modern clocks—was a stick fixed upright in the ground. The length of its shadow would be indicated perhaps by small pebbles; and as the shadow moved round the stick, it would be seen to grow shorter before noon and longer after.

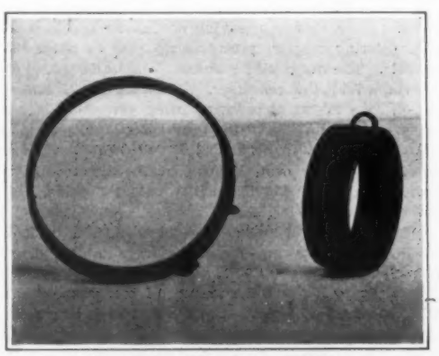
From this simple device the sundial was evolved. This instrument is known to have existed, in one form or another, from very early times, the Egyptians, Chaldeans and Hebrews having all been acquainted with its use. For a description of the theory and formation of dials the reader must be referred to the textbooks which deal with the subject. It may be said, however, that many of the forms were very intricate, and required for their construction the application of complicated trigonometrical formulæ. This was especially the case with the various kinds of small, portable sundials (perhaps the forerunners of the idea embodied in our modern watches), three of which are illustrated in accompanying photographs. The commonest and most useful form, however, was the familiar dial mounted upon a pedestal, with a fixed, triangular gnomon adjusted to the latitude of the locality for which the dial was constructed.

Obviously the sun cannot be employed as a time-marker at night or during cloudy weather; and in this fact we find the stimulus which forced man to adopt mechanical means for determining definite portions of time. For instance, he called fire to his aid, and many of his early methods are still in use among savage and semi-civilized races. In the sixth volume of the *American Arthropologist*, Dr. Walter Hough cites many examples, among which are the following: The Polynesians skewer together on the mid-rib of a palm leaf a number of kernels of the candle-nut tree (*Aleurites triloba*), and ignite the uppermost one. Each kernel burns to a charred mass in about ten minutes, and must be removed by an attendant when the one next below is ignited. The Marquesans tie bits of tapa at intervals along the torch. In China, time is measured—especially in regard to religious or imperial ceremonials



Rush holders; one with candle socket

—by burning joss sticks of fixed length; while *gong heung*, or time incense, which consists of fire sticks of pressed wood-dust made long or short according to the season, is burnt to mark the five watches into which night is divided. Again, in Western China, where water is raised by immense wheels and sold to the villagers, the price is calculated by the quantity that flows while a given length of joss stick burns; and Chinese messengers, who have only a short time to sleep, put a period to their slumbers in advance by fixing a piece of lighted joss stick between their toes.



Two forms of portable sundials

In Korea, the palace clock consisted of an oiled paper lantern enclosing a rope of hemp soaked in niter. Each hour was divided into four parts by cords tied to the rope, which gradually smouldered upwards, and was renewed each evening. The slow burning of a rope, knotted at regular intervals, has been used as a time-marking device by other races of mankind. "Marked candles," divided into sections each of which was consumed in a given interval, are said to have been invented by Alfred the Great, but they were probably survivals from a still more distant period. This ancient type of clock, in one or other of its forms, appears to have been used by rustics long after timepieces of precision had been invented. Rush lights—made by dipping the prepared piths of rushes into molten fat—were doubtless employed by cottagers in districts remote from the centers of civilization at the beginning of the nineteenth century. A rush light would burn for thirty minutes on an average, and thus give a clue to the passage of the hours.

Crude methods such as those which have just been described necessitated the employment of a time-recorder—a contrivance whereby a permanent register of the hours might be kept. This usually took the form of a stick in which a notch was cut whenever a section of rope or candle burnt through, or a rush light was renewed. A similar plan was adopted by users of hour glasses—another early type of chronometer which consisted of two hollow bulbs placed one above the other, and having a narrow neck of communication. The dry sand contained in one bulb takes an hour to pass into the other, when the instrument must be turned. At what period hour glasses first came into use is not known with certainty, but they were commonly employed in churches during the sixteenth and seventeenth centuries to regulate the length of the sermon. The notched sticks used to register intervals of time must not be confused with the old "tally sticks," specimens of which are still in existence. The latter date from a period when paper was unobtainable. The two sticks were cut from the same block, and were exactly alike. One was kept by the employer, the other by the servant, and similar score marks were made on each. It was necessary that the sticks and marks should "tally" when pay day came round.

In conclusion, the clepsydræ, or water clocks, must be mentioned. In its most primitive form this instrument consisted of a vessel of known capacity, with a small hole in the bottom, which was floated upon the surface of water. When it filled and sank, a definite period of time was marked; and in ancient Rome the

Hourglass, an early timepiece

"King Alfred" Candle

clepsydra was tended by a special slave. But from these simple beginnings, water clocks were brought to a high state of mechanical perfection, and many fine examples exist which bear witness to the inventive genius of mankind. As a branch of hydro-dynamics, the principles which regulate the action of the clepsydra have frequently engaged the attention of philosophers and geometricians; but these instruments are now rarely constructed, while for practical purposes they were long ago completely replaced by weight- or spring-driven timepieces. Exactly when clocks (using the term in its modern sense) were first invented is not certainly known, but we have reason for believing that the date of their origin is much more recent than is commonly supposed. Probably the monks of the middle ages were the first clock makers; and in the twelfth century striking clocks are known to have existed in some of the monasteries. From this period onward, the expression "the clock has struck" is frequently met with in old chronicles, while mention is also made of the hands which marked the flight of the hours.

Is the Sun Due to Explode?

We are told that our sun is of advanced age, as ages are reckoned among suns.

Like all other things in creation, suns are brought into existence, and pass away, or pass out of the class of celestial objects known as suns, or stars.

Man has learned to distinguish age among stars by the color of their light. A white star is a young star; perhaps only a few hundred millions of years of age since it gathered from clouds of hot gases into globular form and started out as an independent sun. Yellowish light denotes middle age, and red or crimson indicates mature age; which, as viewed by humanity, would look like several short eternities.

We are also told that all stars, which are merely distant suns, are shrinking in size as they cool off and contract, and the theory was advanced by George Henry Lepper, that while the volume of the star diminishes through contraction, the heat of the core increases with the pressure brought to bear on it and that when this pressure reaches the limit the pent-up materials explode, and the star, or sun, is reduced to a cloud, or puff of fog, called nebula.

When we consider the extent to which suns contract we are able to form some idea of how much the core is squeezed. Earth is about 93,000,000 miles from the sun. There may have been a time when the sun was large enough to fill up all the room clear out to where we are, or farther. If so, it has contracted 93,000,000 miles from each side, which would give the hot center twice 93,000,000, or 186,000,000 miles less of room; so if we have any suspicion that the center of the sun contains any of the ingredients of which dynamite is made we might allow ourselves to get into "hot water" wondering how long it can stand the pressure, considering that our sun is already growing old and perhaps subject to a decline of his powers of resistance.

Is our sun in danger of blowing up? We may reason not, because we have never seen one explode. On the other hand, we must remember that suns are not made in a hurry, and that they take their own time about what they do, and that while man's knowledge of suns covers only a few thousand years, their ages could not be expressed in any manner intelligible to the human mind. Still we must draw the line somewhere, and although our sun may have weathered the celestial storms of an eternity, that very fact may prove that the time for some variation may soon arrive. Our sun is said to be a variable star and variables of a certain class are those stars which are due to explode!

When our sun explodes, what else will happen?

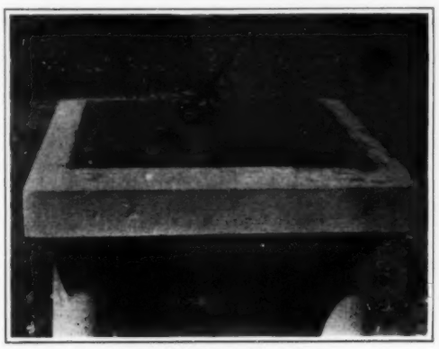
If a little ripple among the superficial layers of the sun, known as a sun-spot, 93,000,000 miles away, upsets the operation of electrical utilities on earth, how much of a jolt will we get when the whole sun is instantaneously resolved to a cloud of gas composed of stone, iron and other substances even heavier and harder, but so hot that they are reduced to vapor, and so elastic that from their sudden release they expand to the limits of the solar system, a region 556 billions of miles in diameter.

In such a maelstrom I apprehend that earth and the other planets and satellites would each flash once like the fire-fly, and be lost in nebula. Will astronomers kindly enlighten us?—Benjamin O. Baxter in *Popular Astronomy*.

Deglet-Knour

Fruit of the Desert

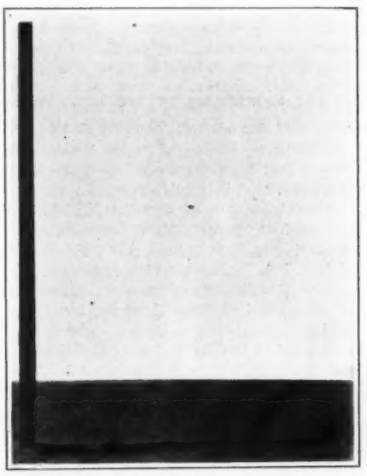
Few people, including those who live by the sale of fruit, are familiar with the term "deglet-knour." It is nothing more recondite than the beautiful Tunis date,



A sundial of familiar form

so plentiful and cheap before the war, but now scarce and dear. The Tunis date was one of the most popular fruits used purely for dessert purposes, but, in common with the banana, its food value was eventually realized. In the days of abundant bread, meat and sugar, only a small percentage of the population took the trouble to ascertain the nutritious and health-giving properties of fruit, but the war has caused millions to become alert on that subject.

There is little need to emphasize the fact that dates are exceedingly valuable. They are rich in natural

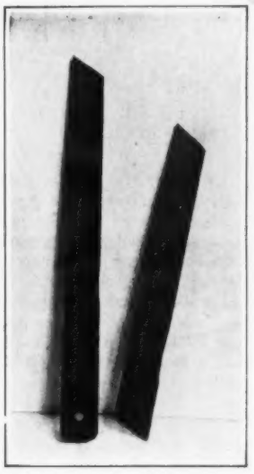


Example of time-stick casting shadow

grape-sugar, a powerful and sustaining nutrient. Arabs, who are proverbially robust, use the fruit in generous quantities; but their economy is a little far-fetched, even in these days, for they give their camels the stones to eat; and of all the jarring sounds one may hear in the course of a peaceful life that of a camel crunching date-stones is one of the most ear-torturing.

Of the many kinds of dates that find their way to this country those known as Tunis are the most highly esteemed both in regard to quality and appearance. Other varieties are perfectly good and wholesome, and

Notched timing stick



Old tally stick, 16th century

well worth attention. There is, indeed, a marked resemblance between the Tunis date and that of Hallowi. Tunis dates are not all of Tunisian origin. The fruit is grown principally in Biskra, Wargla and Tuggourt, in Algiers; whilst in Tunisia the most important centers of cultivation are Nefta, El Oudiane and Tozeur. Dates are a graceful adornment to the branches of the palm-trees that flourish in the oases of the Sahara. Arabs own the plantations which have been instrumental in enriching those wily merchants, whose principal commercial creed is ready cash and plenty of it. At least thirty varieties of Tunis dates flourish in the desert, but of those only one, the Deglet-knour or light-colored date is exported.

When the fruit ripens in October and November, old and young Arabs take their places according to seniority and agility on different parts of the date-palms for the purpose of gathering. Then follow the processes of selecting, grading and selling. In the almost forgotten days of peace the last-named was a long and tedious affair. Arabs are never satisfied with a bargain even when concluded, and they have the temerity to ask for more money after a contract has been settled. The payments for the fruit are made in French currency, and in regard to this it is wonderful to note how astute are the dusky inhabitants of Tunisia concerning the rate of exchange.

In these days the Arab merchants are practically masters of the situation. They know well all that happens in England and other parts of the world, and are quick to take advantage of it. Concerning price their idea is advance in geometrical, not arithmetical, progression, and that is the principal reason why dates are so costly nowadays. Furthermore, no longer are they able to send the worst of their fruit to Russia, so the British public are called upon to pay for that deficiency.

Tunis dates are not dried fruit. After they have been gathered and selected they are sent to Philipville, Gabes or Tunis, and shipped to Marseilles, where the fruit again is subjected to re-selection and carefully packed in attractive style for the English market. They are neither dried nor "cured." In normal times the process is very rapid, but nowadays there are many delays. The fruit does not deteriorate on that account, because its inherent sugar acts as a preservative. —*London Daily Telegraph.*

Photographic Printing Method

It is often desired to obtain one or several prints from a negative as soon as possible after developing, and one way is to give the plate a short washing and then apply bromide paper under water, but of course, without using a printing frame. However, very great care must be used not to scratch the soft gelatin surface of the plate, which would spoil it, of course. The method of drying by alcohol is also well known, but this is somewhat expensive, especially because chemical products are at a high price just at present. A good method is to dry the plate by the heat of an incandescent lamp, after draining off the plate as well as possible. Place the plate gelatin side up and about eight inches above the lamp which is laid for instance on the table (on a suitable backing, of course), and the best plan is to use a holder shaped about like a plate drying rack, laying the plate across the top. The plate will dry in about two hours even in damp weather, and in less time in dry weather. The lamp is preferably held by means of its socket, and thus out of contact with the table.

The Divining Rod—II*

A History of Water Witching

By Arthur J. Ellis

[Concluded from Scientific American Supplement, No. 2199, Page, 125, February 23, 1918]

The adversaries of the divining rod, on the other hand, like Paracelsus and Agricola, condemned its use as a superstitious and vain practice, without attempting to refute the specific arguments advanced by their opponents or flatly denying its supernatural connections.

A third view was that involving a demoniac influence, and Raymond suggests that the adversaries of the rod, including Agricola, may have adopted their attitude of reserve on the question of Satanic influences from a desire to avoid possible serious consequences. Another view, closely related to that of satanic influence, is described by Raymond[3] as follows:

A fourth view was indeed advanced, according to which the operator, as well as the rod, was the recipient of a divinely given faculty. It was no doubt with the purpose of avoiding the odium attached to dealings with the Evil One that the professors of this science, particularly in Germany, surrounded it with ceremonies and formulas of a highly pious character. It is true that the rules sometimes prescribed for the cutting of the twig partook largely of heathen sorcery and astrology. They were indeed, to some extent, unconscious reminiscences of the old Scandinavian, and even of the Aryan mythology. But this was atoned for when the rod was duly Christianized by baptism, being laid for this purpose in the bed with a newly baptized child, by whose Christian name it was afterward addressed. The following formula, cited by Gaetzschmann, may serve as an example: "In the name of the Father and of the Son and of the Holy Ghost, I adjure thee, Augusta Carolina, that thou tell me, so pure and true as Mary the Virgin was, who bore our Lord Jesus Christ, how many fathoms is it from here to the ore?" In this case, the rod was expected to reply by dipping a certain number of times, corresponding to the number of fathoms.

It is readily conceivable that the motive for surrounding this practice with a religious atmosphere might not have been altogether a belief in its divine character, for at that time anyone found engaged in mysterious works was in danger of being charged with sorcery and burned to death.

In Cornwall the belief was common among the miners and still persists as a tradition, that the divining rod was guided to the ore deposits by the pixies, the fairy custodians of the mineral treasures of the earth.

Not only did the abstract discussion of this subject engage the attention of persons in all classes of society, but nobles and peasants, priests and philosophers —representatives from every class—busied themselves trying to locate ore deposits by means of forked twigs. Probably the most prominent diviners at this time were Baron de Beausoleil (Jean-Jacques de Chatelet), 1576-1643, and his wife. Beausoleil, who was one of the foremost mining authorities of his day, traveled extensively through the mining regions of Europe, visited America in his study of mining, and received important commissions from dukes and emperors, and even from the Pope. His wife shared his responsibilities and honors. But later they fell from favor through the machinations of rivals, and the fact that they used divining rods and other contrivances was made the basis of a charge of sorcery. After some years of persecution they were placed in prison (1642), the baron in the Bastile and his wife in Vincennes, where they died about 1645. Raymond[3] writes:

"'In magnifying the art of discovering **mines** and springs, and the skill required for this purpose, she [the baroness, in "The restitution of Pluto"] gives a description of the means employed, showing that these hidden treasures are to be detected, (1) by digging, which is the least important way, (2) by the herbs and plants which grow above streams of water, (3) by the taste of the waters which flow from them, (4) by the vapors which arise from them at sunrise, and (5) by the use of 16 scientific instruments and 7 rods [the 7 rods of Basilius Valentinus] connected with the 7 planets," etc.

The first four means were undoubtedly real and really employed. Under the fifth head we have an illustration of what is so common in the alchemistic and other medieval writers, namely, the covering of the facts of nature and the methods of investigation with assumed mystery to hide them from the vulgar".

This raises the interesting question as to the extent to which intelligent persons may have used divining rods in the early days for the sole purpose of concealing from the uninitiated their real methods of prospecting. One can hardly overestimate the respect for the divining rod that would be created among common miners if a man of real ability publicly attributed his success to its use, and it may be that the deep-rooted hold which the superstition obtained on the popular mind was due to just such circumstances as this.

ORIGIN OF "WATER WITCHING"

The above quotation from the Baroness Beausoleil is interesting also for the reason that in it the divining rod is mentioned as a means of discovering springs. The Beausolells are believed to have been influential in bringing about the use of forked twigs in searching for water, although Barrett[10] writes as follows in regard to an account which he finds in a Life of Saint Teresa of Spain:

"Teresa in 1568 was offered the site for a convent to which there was only one objection—there was no water supply; happily, a Friar Antonio came up with a twig in his hand, stopped at a certain spot, and appeared to be making the sign of the cross; but Teresa says, "Really I can not be sure if it were the sign he made, at any rate he made some movement with the twig and then he said, 'Dig just here'; they dug, and lo! a plentiful fount of water gushed forth, excellent for drinking, copious for washing, and it never ran dry."

Barrett regards this the first historical reference to "dowsing" for water, but Mager[11] and Klinckowstroem[12] mention a paper written by Claude Galien in 1630 on the supposed discovery of the Chateau-Thierry mineral water by Baroness Beausoleil as the first reference. At any rate, from about this time on the divining rod was used in southern Europe as much in the search for water as in the search for mines, although, according to Barrett, it was not used for this purpose in England until near the end of the eighteenth century.

This new application of the divining rod no doubt tended to popularize it. It had been of interest chiefly to miners, and outside of mining districts it was probably known only in a vague sort of way. But as a "water finder" it became more generally known, and in the very nature of things its successes must have outnumbered its failures, just as, taking the country over, successful wells outnumber unsuccessful ones.

USE OF THE DIVINING ROD IN DETECTING CRIMINALS

Prior to 1692 the divining rod had been used in trying to locate minerals and water and possibly to some extent for other purposes. But in that year an incident occurred in southern France which added greatly to the notoriety of the divining rod and extended its field of operation into the moral world, in which, according to some writers, rods for divination had their origin. This incident, which is described in great detail by several writers,[13] was the apprehension and identification of a criminal through the agency of a peasant of Dauphiny named Jacques Aymar, who claimed the ability to trace fugitives by the use of divining rods.

Interest in this case was intense and widespread and called forth a large amount of literature. In commenting on the case Barrett[14] says:

"The other one, a hunchback, who was arrested, confessed the crime and was executed: the last person in Europe who suffered that terrible penalty of being "broken at the wheel." * * * Strangely enough the depositions made at the trial showed that Aymar was correct in every detail, witnesses testifying to the flight and halting places of the culprits in the very places Aymar had indicated. * * * Aymar became notorious throughout Europe. He was, however, subsequently somewhat discredited owing to his failure in some tests devised by the Prince de Condé."

But Raymond, in a decidedly more skeptical treatment of the matter, raises some illuminating questions in regard to Aymar's integrity. His comment on the work of Aymar[15] includes the following statements:

"This man, Jacques Aymar by name, was sent for—or rather it was not necessary to send for him, since he proved to be already on hand in the city by the time it was decided to engage his services. This fact is significant as giving the key to what turned out to be an extraordinary piece of clever detective work. A careful analysis of the numerous official and other records of this case shows it to be quite possible that the diviner had obtained important clues before he was publicly set to work. * * * The subsequent tracking of a hunchback would be no very difficult matter. * * * But this achievement of the rod, attested as it was by official records and by the public confession and execution of the criminal made a great sensation in France. * * * Aymar was called to Paris, where both the court and the savants interested themselves greatly in his mysterious powers. Many marvelous feats are reported of him there; but the shrewd and rigorous experiments of the Prince de Condé exposed the emptiness of his pretensions * * *. As late as 1703 this man was employed during the civil war to point out with his divining rod Protestants for massacre, under the plea of punishment for crimes they had committed."

SCIENTIFIC CONTROVERSIES

RAYMOND

In 1883 R. W. Raymond[16] published his essay on "The divining rod," which contains a historical outline of the subject and a set of conclusions based especially on the works of Chevreul. It concludes with the following highly rhetorical epitaph on this venerable superstition:

"To this, then, the rod of Moses, of Jacob, of Mercury, of Circe, of Valentin, of Beausoleil, of Vallemont, of Aymar, of Bleton, of Pennet, of Campetti—even of Mr. Latimer—has come at last. In itself it is nothing. It claims to virtues derived from Deity, from Satan, from affinities and sympathies, from corpuscular effluvia, from electrical currents, from passive perturbatory qualities of organo-electric force are hopelessly collapsed and discarded. A whole library of learned rubbish about it which remains to us furnishes jargon for charlatans, marvelous tales for fools, and amusement for antiquarians; otherwise it is only fit to constitute part of Mr. Caxton's "History of human error." And the sphere of the divining rod has shrunk with its authority. In one department after another it has been found useless. Even in the one application left to it with any show of reason it is nothing unless held in skilful hands, and whoever has the skill may dispense with the rod. It belongs, with "the magic pendulum" and "planchette," among the toys of children. Or, if it be worthy the attention of scientific students, it is the students of psychology and biology, not of geology and hydroscopy and the science of ore deposits, who can profitably consider it."

BARRETT

In 1891 W. F. Barrett,[17] professor of physics in the Royal College of Science for Ireland, in the interest of the Society for Psychical Research, undertook a very laborious investigation of water witching, or dowsing, as it is called in England, and later published his results in two large volumes.

Barrett concluded that the movement of the rod or forked twig is due to unconscious muscular action arising from subconscious and involuntary "suggestion" impressed on the mind of the dowser, and that this subconscious suggestion may be merely an autosuggestion or a suggestion derived through the senses from the environment, but that in a certain number of cases it appears to be due to a subconscious percep-

*Abstracts from Water-Supply Paper No. 416 issued by the U. S. Geological Survey, Dept. of the Interior.

[3]Raymond, R. W., The divining rod: Am. Inst. Min. Eng. Trans., vol. 11, p. 419, 1883.

[9]Idem, pp. 420-421.

[10]Barrett, W. F., Psychical research, p. 171, 1911.

[11]Mager, Henri, Les moyens de découvrir les eaux souterraines et de les utiliser, p. 327, 1912.

[12]Klinckowstroem, Graf, Carl v., Bibliographie der Wünschelrute, p. 38, 1911.

[13]Baring-Gould, Sabine, Curious myths of the middle ages, p. 54, 1894. Mager, Henri, Les moyens de découvrir les eaux souterraines et de les utiliser, pp. 362-365, 1912.

[14]Psychical research, ch. 12, p. 172.

[15]Raymond, R. W., The divining rod: Am. Soc. Min. Eng. Trans., vol. 11, pp. 424-427, 1883.

[16]Raymond, R. W., The divining rod: Am. Inst. Min. Eng. Trans., vol. 11, pp. 411-446, 1883. Published also in U. S. Geol. Survey Mineral Resources, 1882, pp. 610-626, 1883.

[17]Barrett, W. F., On the so-called divining rod or Virgula divina: Soc. Psych. Res. Proc., vols. 13 and 15, 1897, 1901.

tive power commonly called clairvoyance. His conclusions were therefore in a sense favorable to water witching, although completely refuting all claims that there is any physical relation between the underground water and the forked twig or its manipulator, and definitely relegating the subject wholly to the obscure realm of occultism with other varieties of fortune telling.

MAGER

In all its weird history no more extravagant and absurd claims were ever made for the divining rod than those which are maintained at the present time by Henri Mager. Mager is an enthusiastic champion of divining rods, magic pendulums, and his own mechanical device for locating water and ores. His hypotheses are presented in his three elaborate volumes—"Les moyens de découvrir les eaux souterraines et de les utiliser," 1912; "Les sourciers et leurs procédés," 1913; and "Les influences des corps minéraux," 1913—and in his pamphlet "A new method for the study of mining fields and for finding ore embedded in deep ground," 1914. At almost every step in the advance of science and philosophy some one has attempted to explain the supposed operation of the divining rod by means of the latest scientific theories, and Mager's work is in accord with precedent. His claims are built on dicta or speculations in which use is made of the terminology of students of radioactivity and electromagnetism.[11]

RECENT INVESTIGATIONS

It remains to be stated that there are several societies in Germany whose sole object is said to be the study of the divining rod, and that a subcommittee of the commission of scientific studies in the bureau of waters and forests of the department of agriculture of France was appointed in 1910 to investigate the subject and in 1914 was still investigating.

MECHANICAL WATER FINDERS

About 1640 Baroness Beausoleil, in "The restitution of Pluto," listed, among means of discovering mines and springs, the use of 16 "scientific instruments." This is the earliest reference to such instruments that has been discovered in the preparation of this report, and it is a matter of considerable interest that even at this early date a single prospector should manifest so wide an acquaintance with devices for finding water and ore. It is certain that Beausoleil's 16 were the forerunners of a prolific race. At least 24 patents of this nature are now on file in the United States Patent Office, but this is no index to the number which have been rejected and which have never been offered for patent in this country, not to mention foreign inventions.

Most of the present devices are magnetic or electrical instruments, which, taken together, cover almost every application of magnetism and electricity. They range from ordinary dip needles to telephones and devices using wireless waves. Among the most widely advertised instruments of this kind are W. Mansfield's "Patent automatic water and oil finders," Henri Mager's "Indicator of current ground water," and Adolf Schmids's "Device for detecting subterranean waters." Mansfield's instrument was denied a patent in the United States on the ground that it was anticipated by the patent of Adolf Schmids. Mager's instrument, which is described in all his publications, is admitted by him to be only a modification of Schmids's device.

In the letters patent[12] of the Schmids device it is stated that the apparatus will "indicate certain atmospheric changes, the nature and cause of which are not yet understood but which manifest themselves in a peculiar way in the neighborhood of the source and course of subterranean waters by rapid oscillations of the pointer of the device."

The instrument is described as a hollow glass cylinder having an axis around which is spirally wound a soft-iron wire in layers that are separated from one another by paraffined paper, and at intervals by layers of tinfoil. The outside layer of the spool is covered with paper. The wire of this spool forms an open circuit. The end of the spool is covered with a glass dial plate having at its center a pivot on which a pointer or needle oscillates.

It is claimed that when the instrument is in the vicinity of a source or a stream of subterranean water the needle will after a time oscillate rapidly.

In the literature advertising its "automatic water and oil finders," circulated by the Mansfield Co., of Liverpool, England, the following claims are made:

The principle on which the instrument works is the indicating of the presence of currents which flow between earth and atmosphere, and which seeking the path of greatest conductivity, are always strongest in the vicinity of subterranean water courses, the waters of which are charged with electricity to a certain degree. In taking observations, wooden pegs are placed at intervals of 20 paces in a direction usually southeast to northwest. The instrument is tried over each of these pegs in turn, and should the needle move on any one of them, tests are made all round it, and the spot where the greatest movement of the needle is obtained is where the boring should be made. If the needle does not move subterranean water does not exist under the spot where the instrument is fixed. * * * The instrument indicates water courses flowing underground in a natural state and not water pipes or sources that have sprung up to daylight.

Systematic magnetic observations have been made for about 70 years, and a complete magnetic survey of the earth, under the direction of the Carnegie Institution of Washington, has been in progress for a number of years, but this survey has not yet disclosed the existence of local earth-air currents on which to base a method of utilizing such currents in determining underground conditions. In view of this lack of knowledge any invention based on the assumption that such currents exist, as, for example, the Schmid patent, is subject to the general criticism that it is unsound in principle, or at least that, like the divining rod, it can be subjected to no conclusive scientific test. The practical use of such instruments, moreover, seems to be incompatible with the known instability of the magnetic and electric state of the earth and the atmosphere, in which disturbances of greater or less degree are constantly taking place. Investigations[13] have shown that magnetic disturbance is nearly continuous; that an entirely undisturbed day is abnormal. Some magnetic disturbances are local; others affect the whole earth simultaneously.[14] Bauer[15] writes:

"The magnetic disturbances experienced by the earth are generally of a very complicated nature and reach at times startling magnitudes. Thus during the most remarkable magnetic storm of which there is any record —the one of September 25, 1909—the compass needle in the vicinity of the city of Washington suffered a change of 5 degrees in the short space of a quarter of an hour and the force acting on it passed through a change during the same period amounting to 10 per cent. of its full value. * * *

I confidently expect, as soon as a complete analysis has been made of magnetic disturbances covering the greater portion of the earth, it will be found that * * * the disturbances will themselves reveal effects from terrestrial, continental, regional and even local causes (earth currents, for example, whose path and intensity depend upon local character of soil, etc.)."[16]

Since the earth's magnetic state is known to be of a very heterogeneous character, requiring an exceedingly complicated mathematical expression for even a very approximate representation, it may be confidently expected that any magnetic change or disturbance, from whatever source it may come and of however simple a type it may originally be, by the time it has entered the earth's field and has impressed itself upon our magnetic instruments, will have been converted into an equally complex type to that of the earth's magnetism itself.[17]"

Further study of this subject tends merely to strengthen the belief that magnetic disturbances may be due to causes so many and various that no confidence can reasonably be placed in any claim that the oscillations of a magnetic needle indicate the occurrence of available ground water, much less the depth at which water can be reached or the quantity that can be obtained; and it confirms the opinion that, in the present state of knowledge, any such claim is purely speculative.

[An extensive Bibliography accompanies the paper.]

Insects That Eat Tobacco

THE destruction wrought by the tobacco beetle has become so pronounced in this country that the United States Department of Agriculture has issued a bulletin on the subject for manufacturers and dealers in tobacco products. While tobacco is known as an insecticide or as a repellent for some insects, it has no terrors for this beetle, which prefers the expensive, sweet, mild tobacco, especially the best Turkish leaf. A very few of them, in factory or show room, may start an immense amount of damage.

The beetle is a small brownish insect only one-tenth of an inch long. Most of the damage is done by the young, or larvæ, a yellowish-white grub somewhat larger than the adult. While it is impossible to estimate the total losses in a year, the figures for the industry as a whole are said to be very large. Single firms report losses as high as $25,000 a year.

The burrows of the larvæ, left filled with dust and excrement, may extend in any direction, and may go through the wrapper of cigar or cigarette at any point. Injured cigars do not draw well, and burn unevenly; moreover dust and trash is likely to be drawn into the mouth of the smoker. Leaf tobacco in storage, and chewing tobacco also, may be badly worm eaten and made unsalable.

Although the beetle is now found in all parts of the temperate zone, its spread is from warm tobacco-growing countries such as Cuba and the Philippines, where it breeds throughout the year. From these countries the insects are sent out constantly in shipments of cigars or leaf tobacco, either in the egg, larval, or pupal stages, or as adult beetles.

The insect lives in the tobacco during its whole life, and thrives best with considerable warmth and moisture. In the Southern States there are three or four generations in a year. It does not live on growing tobacco and is not introduced from the fields.

Although a number of insects prey on the beetle, methods of artificial prevention and control are necessary. Prevention is important, and all places of manufacture and storage should be thoroughly screened and all refuse material, damaged stock, etc., promptly destroyed. The protection of the finished product is particularly important, since with most classes of manufactured tobacco the process of manufacture frees it from all stages of the beetle present in the raw material, including even the eggs, which are only loosely attached to the tobacco leaves.

Cold storage affords a good method of control, temperatures between freezing and 65° F. being effective as long as the tobacco is in storage, but the activity of the beetle is resumed after such storage. Lower temperature, such as 12° F., for from one to four weeks kill all stages. Care must be used to bring the cigars out on dry days. This prevents sweating and consequent discoloration or warping of the containers. Winter freezing kills, and sudden and extreme changes of temperature are particularly effective. High temperatures, around 140° F., will serve as well as freezing.

Fumigation with hydrocyanic-acid gas is sure when carried out properly, but the process of generating the gas must be understood thoroughly and the greatest precautions taken, as it is a deadly poison. Carbon bisulphid is less effective but more easily used and less dangerous to the operator. When mixed with air its vapor is explosive in about the same degree as gasoline, however, and it must therefore be handled with care, and should not be breathed unnecessarily. In spite of the odor of the chemical it does not taint the tobacco or affect its aroma and quality.—*Weekly News Letter of the Department of Agriculture.*

A Method of Observation and Measurement of Rapid Periodic Magnetic Phenomena

THE method employed is to make vibrate a small piece of metal attached to a Koenig manometric capsule. An examination of the deformations of the flame due to the vibrations transmitted to the capsule enables a study of the magnetic field of the vibrator to be made both as regards magnitude and variation. So as not to introduce perturbation a glass capsule is employed. The metal is a disc of iron, 18 mm. thick, with a hole 6 mm. in diameter in its center; it is fastened to the membrane on the outside of the capsule. The capsule is traversed by a current of coal-gas at a constant pressure of 13 mm. of water. The electro-vibrator is placed perpendicularly to the membrane and 62 mm. distant from it. The observations of the flame are made by means of a rotating mirror, or the results may be registered photographically.—Note in *Science Abstracts* in an article by P. Woog and J. SARRIAU in *Comptes Rendus.*

[11] See Joly, J., Radioactivity and geology, 1909, and Bauer, L. A., The physical theory of the earth's magnetic and electrical phenomena: Terrestrial magnetism and atmospheric electricity, vols. 15 and 16, 1910, 1911.

[12] Patent No. 841188, Jan. 15, 1907.

[13] Bauer, L. A., Analysis of the magnetic disturbance of Jan. 26, 1903, and general considerations regarding magnetic changes: Terrestrial magnetism and atmospheric electricity, vol. 15, pp. 22, 24 and 25, 1910.

[14] Schuster, Arthur, The diurnal variation of terrestrial magnetism: Roy. Soc. London Philos. Trans., ser. A, vol. 208, pp. 184-185, 1908.

[15] Bauer, L. A., The physical theory of the earth's magnetic and electric phenomena: Terrestrial magnetism and atmospheric electricity, vol. 15, p. 111, 1910.

[16] Op. cit. (Analysis, etc.), p. 25.

[17] Idem, p. 22.

The Development by X-Rays of Two New Fields

How the Radiographer Has Been Able to Throw Light in Unexpected Places

By L. E. Dodd

X-RAYS is a live subject. It is today being studied by most precise scientific methods, while the daily practical application of X-rays to immediate human needs is constantly leading to refinements and improvements. It is a live subject not alone with the Roentgenologist, but with the general public that realizes the high value to the surgeon and to his patient of X-ray photographs, and also with the investigator engaged in research in pure science, to whom indeed we are chiefly indebted for X-rays. At a time when people demand that things move this is a subject decidedly up to date.

Between pure and applied science the masses of the people do not always clearly distinguish, or, if they do, to them the first is likely to stand for what is theoretical and vagarious, hence of somewhat doubtful value, while the second means something practical, therefore entirely worthy of respect and support. After a research worker in pure science has proudly shown his apparatus in operation to the average practical-minded person, the questions most likely to fall from the visitor's lips are, "What good is it? Just what do you expect to do with it?" And immediately a satisfactory explanation in answer to these questions thrusts upon the research worker another knotty problem. But though such explanations may often fail, nevertheless pure science is ever the mother of applied science, even though the relationship may not always be made clear to the uninformed.

Within the last five years two distinct new fields have been developed by X-rays in the hands of research workers in pure science. As a contribution to knowledge this development is of primary importance, and with it the present article deals. To refresh the reader's memory, the method of production of X-rays will be rapidly reviewed, and the nature of the rays themselves discussed. The usual source of the rays is the anticathode, or target, of an X-ray tube. Upon this target are shot cathode rays, which are negatively charged particles, electrons. The cathode rays are projected from the surface of the cathode in a perpendicular direction. The cathode, in the older type of tube (as distinct from the Coolidge type), is made cup-shaped so that the cathode rays converge and are "focused," with the focus lying on the target, so that only a relatively small area on the target receives them. From this small area the X-rays, or Roentgen waves, are given out at all angles with the plane surface of the target. Their origin is in the atoms of the metal which the high velocity cathode rays have penetrated and so agitated that they emit the Roentgen waves, having the velocity of light. The particular type of Roentgen radiation from a target, determined by the different wave lengths making up this radiation, depends on the metal of which it is made.

With the earlier history of X-rays people are fairly familiar. It was only a little over twenty years ago that Professor Roentgen discovered "almost accidentally," but indeed while engaged in work in pure science, the rays that have been named after him. Subsequent experimental work, accompanied and guided always by the theory of the pure scientists, has established that these rays are waves, of the same nature as light and wireless waves, but having much shorter wave lengths. Thus, if we were to take the different "radiations" in the order of decreasing wave length we should name wireless waves first, whose lengths are measured in meters; then radiant heat waves, with lengths from 0.35 mm. down to 0.0001 mm.; then light waves, of lengths short enough to be sure, when compared with an ordinary unit of length such as the inch, but great when compared with the lengths of the waves of the Roentgen rays.

To "visualize" to some degree the size of the Roentgen waves let the reader fix his attention on a train of these waves an inch long. Inside this inch there are about 250 million separate and distinct waves. If now he imagines this wave train to be stretched out so that each wave in it attains a length of one inch, the train itself will have reached a length of some 4,000 miles.

It may be added as a matter of interest that there are waves still shorter than those of the X-rays; viz., the gamma rays given off by radioactive substances. These waves are in reality X-rays of short wave lengths, which may be as much as a hundred times shorter than the shortest X-rays, as usually produced, thus far measured. All these types of waves—wireless, heat, light, and Roentgen, together with the gamma rays—are designated by the general term "radiation," or "electromagnetic waves."

It is clear that wherever we have waves we must have a medium in which the waves travel. The mind cannot imagine waves traveling through *nothing*. Water waves travel in water, sound waves in air, or other material medium, the waves of a vibrating piano wire along the wire, and so on. But radiation waves must travel in some medium different from ordinary matter. For light seems to travel as easily through a good vacuum as through air—if not more easily. So in order to make up for the lack of a known medium ("known" in the same sense in which ordinary matter is known), men have called to their assistance a hypothetical medium which they have named the ether. (It has sometimes been called the "luminiferous," or light bearing, ether.) The ether—it is difficult to believe, in view of the convincing experimental evidence in favor of the wave theory of the different kinds of radiation, that it is a substance purely imaginary—is supposed to

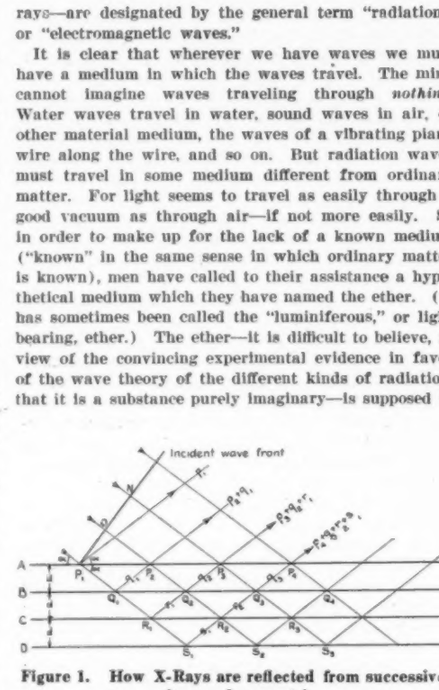


Figure 1. How X-Rays are reflected from successive planes of a crystal

fill all space and to penetrate all matter, which may be regarded as imbedded in the ether. When ether waves traverse matter they are definitely modified by the presence of the matter, so that we have such familiar effects as the focusing of light rays by means of a lens, the reflection of light from a mirror, or the complete stoppage of light by a black surface.

The focusing (refraction) and reflection of light waves is a common phenomenon, and it is not surprising that wireless waves, and radiant heat waves, since they are of the same nature as light waves, can be reflected and refracted. But at the same time one would expect to be able to do everything with Roentgen waves that can be done with light, heat, and wireless waves, such as focusing and reflecting them. Hertz, who was the first to produce wireless waves, had succeeded in refracting them with large prisms of resin, paraffin, and other dielectrics, and had reflected them from both plane and curved metal surfaces, showing that they followed laws similar to those governing light. Waves of radiant heat can also be reflected, as is well known, and can be spread out, with a prism of rock salt, into a spectrum, just as sunlight is spread out with a glass prism to form a visible spectrum.

It was natural for scientists to seek evidence of the wave nature of X-rays by attempting to refract and reflect them with material substances in the manner that had been successful with the other kinds of electromagnetic waves. Five or six years ago Chapman tried to refract the rays with a prism, among other materials, of ethyl bromide vapor, a gas susceptible of strong ionisation by the rays. But this vapor showed not the slightest measurable traces of refractive power for X-rays. Many other attempts at refraction of X-rays have been made, including those of Roentgen himself with "prisms of a variety of materials, such as aluminum, ebonite, and water." No confirmation of the wave theory of X-rays, however, was obtained from this source. Furthermore, it is impossible to reflect regularly Roentgen waves from the smoothest mirror, for although the surface of such a mirror is "smooth" to light waves, it is "rough" to the Roentgen waves, which are a thousand times shorter, so that while the light waves are "regularly" reflected from the mirror, the Roentgen waves are reflected only diffusely.

It remained for Professor M. Laue of Munich to point the way that has not only established the wave theory of X-rays, but has incidentally opened up two new and distinct fields wherein X-rays are the chief instrument, and a very powerful one. Only five years ago—to scientists it is already becoming an old story—on the theory that X-rays are really waves, Laue proposed the idea that natural crystal surfaces might be "smooth" enough to reflect regularly these short waves. He supposed that by successive reflections of the parts of an incident wave striking the geometrically arranged atoms supposed to be making up the crystal, interference effects, similar to those obtained with light by means of a grating, might be obtained. In other words the crystal might act as a grating for the X-rays. Laue's theory, worked out by him mathematically, was tested and strikingly confirmed by Friedrich and Knipping in 1913, who secured interference effects photographically. Some hours, indeed, were required for exposures of the plates, since "by far the greater proportion of the rays were unaffected and undeviated by the crystal," passing on through the crystal in the ether permeating it. These interference effects are explained most convincingly on the wave theory, and not only indicate the true nature of X-rays, but tell us very plainly that planes made up of atoms actually form the internal structure of crystals. The theory of interference of Roentgen waves upon passage through or reflection from a crystal has been worked out not only by Laue but more satisfactorily by W. L. Bragg in England. The theory beautifully explains the experimental facts in their minute details.

On Bragg's view a crystal is regarded as made up of planes of atoms (Laue's treatment of the theory centered attention upon the individual atoms of the crystal), and the interference effects are explained on the basis of successive reflections from these planes. At the suggestion of C. T. R. Wilson, Bragg was led to try the cleavage planes of crystals for regular reflection of Roentgen waves. Mica, with its very definite cleavage planes, was subjected to experiment. The reflection of X-rays from it was so good that only a few minutes' exposure was necessary for a distinct impression on a photographic plate. This reflection is really an interference effect, as will be seen, and is due to the given trains of incident Roentgen waves undergoing repeated partial reflections from the successive planes of the crystal as the waves penetrate into its body. While all the cleavage planes of the mica sheet used for the reflection reflect "regularly" (angle of incidence of a beam of some width equal to its angle of reflection), it is only at definite values of the angle of incidence that the waves reflected from the different planes are all "in the same phase." (By wave trains being "in phase" is meant that the crests and troughs, or what correspond to them, of the different trains are coincident, so as to produce a resultant wave train of much more energy than that of a train reflected from a single plane.

Thus the "regular" reflection of X-rays that is appreciable in amount from, say, mica, is due to regular reflection plus interference, which is the adding together of a number of wave trains to produce a resultant train. This regular reflection of X-rays from a crystal occurs then in appreciable degree only at definite angles, α, determined by the relation

$$n\lambda = 2d \cdot \sin \alpha,$$

where λ is the given wave length concerned in the reflection; n is the "order" of the reflected beam, being a whole number, 1, 2, 3, etc.; d is the constant distance between reflecting planes in the crystal, and α is the "glancing angle" of incidence, or angle between incident beam and crystal surface. Since the largest possible value of $\sin \alpha$ in any case is unity, the value of n for a given crystal can never be greater than $2d \div \lambda$.

The equation above is simply derived. Consider the successive planes, A, B, C, etc., in a crystal, also a beam of X-rays incident at the glancing angle α, (Fig. 1), with glancing angle of reflection, α, equal to the glancing angle of incidence. The "wave fronts" in the beam may be taken as sections of planes, since the distance, d, between crystal planes is very small compared with the extent of the actual wave front. Consider one of these wave fronts making a section P-O-N with the plane of the paper, and itself perpendicular to this plane. Such a wave front is necessarily perpendicular to the direction in which the wave train is traveling, thus perpendicular to the beam and the "rays" making up the beam. (A "ray," physically, is a minute fractional part, or filament, of the beam, of exceedingly small cross-section, and for purposes of analysis may be regarded as a geometrical line.)

The ray X_1, striking crystal plane A at the point P_1,

loses a very small fraction of itself by reflection at that plane. Let this ray, reflected by the first crystal plane, A, be represented by p_1. It has been splintered off, so to speak, from the incident ray X_1, and has an angle of reflection equal to the angle of incidence. The incident ray X_1 penetrates, undeviated from its original direction, to the next crystal plane, B, suffering another splintering off of another weak reflected ray, q_1, at the point Q_1 on crystal plane B. Similarly at R, on the next crystal plane C, the incident ray X_1 loses another small part of itself in the reflected ray r_1, and so on for a very large number of the successive planes, D, E, F, etc., in the crystal, the incident ray X_1 slowly decreasing in intensity all the time. (These crystal planes are of course exceedingly close together, their distance apart in rock salt being about a hundred-millionth of an inch.) The reflected rays, q_1, r_1, etc., pass or out of the crystal without change in direction, so that when they emerge in the air they are all parallel to the first reflected ray, p_1, produced at the first plane A.

We next select another ray, X_2, of the incident beam of X-rays. X_2 is parallel to X_1, and is so chosen that it strikes plane A at P_2, the point where the reflected ray q_1 emerges from the crystal. This second incident ray, X_2, is affected by the different crystal planes in the same way as is X_1. Thus, from the point P_2 there issue two reflected trains, p_2, q_1, which add themselves together to form a single resultant wave train going out from the crystal. From the symmetry of the figure the point Q_2 on plane B where X_2 strikes it, is the same point where the reflected ray r_1 crosses that plane. In like manner we select another ray, X_3, in the incident beam such that it strikes crystal plane A at the point P_3 where the combined reflected rays, q_2, r_1, emerge into the air. Thus from point P_3 there issue three trains of reflected waves combined to form a single resultant train. And so on.

The resultant wave train issuing from P_2 will be most intense when the separate trains, p_2, q_1, are "in phase," that is, join each other so that crest falls on crest and trough on trough. Now the waves in the rays X_1, X_2, X_3, etc., are all in phase at the respective points, P, O, N, in the same wave front. Then the reflected rays, p_2, q_1, will be in phase at and beyond P_2 when, and only when, the path difference,

$$\Delta = P_1 Q_1 + Q_1 P_2 - OP_2,$$

is an integer multiple of the wave length λ; *i. e.*, when $\Delta = n\lambda$. But

$$P_1 Q_1 = Q_1 P_2 = \frac{d}{\sin \alpha}$$

$$OP_2 = P_1 P_2 \cos \alpha = \frac{2d \cos \alpha}{\tan \alpha} = \frac{2d \cos^2 \alpha}{\sin \alpha}$$

$$\text{So} \quad \Delta = 2d \left(\frac{1 - \cos^2 \alpha}{\sin \alpha} \right) = 2d \sin \alpha$$

For the condition of maximum mutual reinforcement of the reflected rays, p_2, q_1, etc., we have therefore $2d \sin \alpha = n\lambda$. Putting $n = 1, 2, 3$, etc., successively we obtain the necessary glancing angles of incidence, α, the maximum number of which, with a given crystal, is fixed, as before stated by the relation, $n = 2d \div \lambda$.

Thus there are possibilities of good regular reflection at different angles, α_1, α_2, etc., as shown roughly in Fig. 2. However, the "first order spectrum," that is, the reflected beam for which $n = 1$, is the one in which our interest particularly centers. When any one of these angles, α, is regarded it is seen from the symmetry of the figure that the reflected rays q_2, r_1, are in phase at Q_2, likewise the rays p_2, q_1, r_1, are in phase at P_2, and so on. By selecting equidistant rays of the incident beam, X_1, X_2, X_3, etc., suitably spaced, we have necessarily selected corresponding reflected rays, Y_1, Y_2, Y_3, etc., which are resultant rays each made up of separate reflected rays.

The question arises as to the disposal of the incident rays contained in the beam between X_1 and X_2, between X_2 and X_3, and so on. Evidently we have thus far dealt only with a system of selected rays, X_1, X_2, X_3, etc. But it is easily seen that an unlimited number of other similar systems of rays may be dealt with in exactly the same way, so that no rays of the incident beam are left out of consideration. For each of these systems of incident rays there will be a corresponding system of reflected rays, and so for the incident beam taken as a whole there will be a reflected beam, which has maximum intensity when the incidence angles are chosen according to the formula just derived.

In this formula, $n\lambda = 2d \sin \alpha_1$, there are two interesting and important quantities which are respectively fundamental in the two new fields in X-rays to which this article has chief reference; viz., d, the distance between atomic planes in a crystal, and λ, the wave length of the Roentgen radiation employed. One of the two fields is devoted to comparing values of λ, keeping d constant, the other to comparing values of d, keeping λ constant. Working with the first order spectrum ($n = 1$), in the first case λ is proportional to $\sin \alpha$, and in the second case d is inversely proportional to $\sin \alpha$, both of these relations following at once from the formula. A constant d is obtained in practice by using the same crystal, whereby different wave lengths may

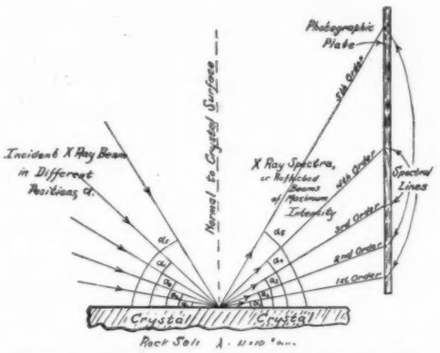


Figure 2. The five reflection angles of rock salt for an X-Ray wave-length of 11×10^{-9} centimeters, or (roughly), 4-billionths of an inch

be compared, such as the characteristic wave lengths of a given metal used as target in the X-ray tube, and the characteristic wave lengths of different metals used as targets. Or, a constant λ is obtained in practice by using always the same wave length from a given metal as target, and in this way the values of d in different crystals can be compared.

The experimental arrangement in either case would be essentially that found in the X-ray spectrometer devised by the Braggs, excepting perhaps the substitution of a photographic plate for their ionisation chamber, as a means of detecting the "spectral lines." In the Bragg X-ray spectrometer the X-ray tube is enclosed in a lead box. The X-ray beam to be used issues from the box through a suitable slit in the wall. It falls on the crystal, which is mounted on a table capable of being rotated so as to give any desired angle of incidence, α, of the beam with the crystal surface. The reflected beam then passes into an ionisation chamber

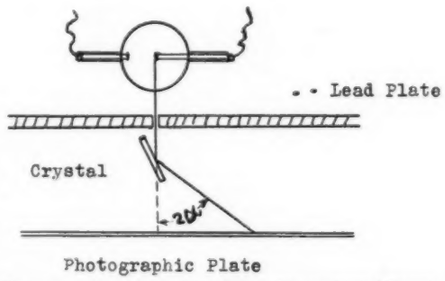


Figure 3. One arrangement for catching reflected Roentgen beams on the photographic plate

which is electrically connected with an electroscope. The rate of movement of the electroscope leaf indicates the intensity of ionisation, which in turn depends on the intensity of the reflected beam entering the ionisation chamber. Since this chamber can also be rotated the positions of the maximum reflected beams corresponding to the different wave lengths in the incident beam can be located.

A stationary photographic plate instead of the movable ionisation chamber may be used to locate the reflected beams of maximum intensities (Fig. 3). If the crystal surface is parallel with the slit in the lead box through which the X-rays issue, the impressions left on the plate by the reflected beams will be straight, dark lines, which are "images" of the original slit as formed by the different wave lengths present, each with its own value of α. These line images on the plate are called "spectral lines." Taken collectively they form the "X-ray spectrum" of the metal of the target in the X-ray tube. The crystal is slowly rotated, during the photographing of the spectral lines, in order that it may pass through continually increasing values of α, since the incident beam is fixed in direction. Whenever the position of the crystal gives the value of α corresponding to a particular wave length in the incident beam, that wave length produces its impression on the plate.

Fig. 2 shows the effect produced by a crystal, in this case rock salt, on an X-ray beam of single wave length, $\lambda = 1.1 \times 10^{-8}$ cms. Since but one wave length is present there is but one spectral line in each spectrum of the different orders. If, say, five wave lengths were present at the same time in the incident beam, each wave length, with its own values of α, would have a spectral line representing it in each order spectrum. Thus each spectrum would contain five distinct spectral lines, corresponding respectively to the five lines in each of the other spectra.

So we have these two new fields of exact research, that of measurement of wave lengths of X-rays, and that of crystal measurements. Data obtained in the first field have already yielded very definite information regarding the internal structure of the atom, while the second field affords an extension of crystallography of the highest value. The two fields together furnish most valuable and exact information not only about the distribution of atoms and molecules in the building up of crystals, but also of the interior structures of individual atoms.

Pioneer work in the first field was done by the Braggs and particularly by Moseley, whose researches were published in the *Philosophical Magazine*, December, 1913, and April, 1914. Regarding Moseley and his work our own Professor Millikan says: "At the age of twenty-seven he had accomplished as notable a piece of research in physics as has appeared during the last fifty years. * * * In a research which is destined to rank as one of the most brilliant in conception, skillful in execution, and illuminating in results in the history of science, he threw open the windows through which we can now glimpse the sub-atomic world, with a definiteness and certainty never even dreamed before."

Moseley established a relation among the elements that stands on a level with Mendelejeff's work in their periodic arrangement according to atomic weight. Indeed Moseley's work adds significance to Mendelejeff's table. As Millikan further says, "Moseley's work furnished for the first time convincing proof that there can be no more than 92 elements." Moseley found that all the different elements, when used as targets in X-ray tubes, give off characteristic wave lengths such that the atomic numbers (determined by arranging the elements in the order of increasing atomic weights, which is the order of Mendelejeff's table) increase in the same ratios as the square roots of the corresponding characteristic wave lengths decrease. In other words, the product of the atomic number and the square root of the wave length is a constant. Since the X-rays have their origin in the atoms themselves of the metal of the target, by the establishment of this important relation our theory of atomic structure has received clarification and further guidance.

Regarding Moseley's work Millikan further says: "His work is, in brief, evidence from a wholly new quarter that all the elements constitute a family, each member of which is related to every other member in a perfectly definite and simple way. It looks as if the dream of Thales of Miletus had actually come true and that we have not only found a primordial element out of which all substances are made, but that that primordial element is hydrogen itself. * * * It seems highly probable from Moseley's work that we have already found all except four of the complete series of different types of atoms from hydrogen to lead, that is, from 1 to 82, of which the physical world is built. From 82 to 92 comes the group of radioactive elements, which are continually transmuting themselves into one another, and above 92 (uranium) it is not likely that any elements exist. * * * The Moseley experiments have gone a long way toward solving the mystery of spectral lines. * * * How brilliantly, then, have these recent studies [in X-rays] justified the predictions of the spectroscopists [who have heretofore worked with the spectral lines due to the different wave lengths in visible light], that the key to atomic structure lay in the study of spectral lines!"

The field of crystallography has presented, until the discovery of the remarkable effect of crystals on X-rays, much of the mysterious, seemingly almost hopelessly hidden from the scrutiny of men. During the last century scientific attention has been more and more centered on the molecule and the atom as the seat of causes of physical phenomena. It was only natural that problems relating to crystal structure should also, sooner or later, be attacked from the standpoint of molecular theory. The molecular point of view respecting crystals was definitely introduced by Bravais in 1850, who supposed that the molecules of a crystal are

distributed so as to form a space lattice. This notion was indeed the basis of Laue's happy idea of the possibility of reflecting X-rays from the atomic planes in crystals. With the powerful new method of X-ray crystal analysis a number of crystalline forms have already been successfully studied, among them rock salt, the chloride, bromide, and iodide of potassium, Iceland spar, fluorspar, diamond, sylvine, zinc-blende, selenium, and iron pyrites.

The intensity of Roentgen waves reflected from a single crystal plane is exceedingly low. By reinforcement of a large number of wave trains reflected from successive crystal planes in the manner already studied the intensity of the reflected beam may be much increased. But even under the best conditions this intensity is still so low as to require with most crystals a long exposure of a photographic plate to obtain definite impressions of the spectral lines. Apparently the only conceivable way in which the intensity of X-rays could be further increased is by focusing them, and this has seemed hopeless because of their stubbornness in resisting completely all efforts that have been made to refract them. But X-rays have, nevertheless, been successfully focused during the past year, 1967, and how this was cleverly done by an American will be told in a following article, of which the present article may be regarded as the basis.

Gas Warfare*

Methods and Materials Now Extensively Employed on the Western Front

By S. J. M. Auld, British Military Mission

ALL I can do in the short time available is to give you, if I can, a general idea of what gas warfare really means on the Western Front at the present time. Some of you may have gotten the idea that gas is just an incident, and that there is not as much attention being paid to it as there was two years ago. That idea is entirely wrong. Gas is used to a tremendous extent, and the amount that has been and is being hurled back and forth in shells and clouds is almost unbelievable. I will try to give you a general idea of what is occurring and make the lecture rather a popular than a technical description. I shall also, for obvious reasons, have to confine myself to describing what the Germans have been doing, and will say nothing about what we are doing.

Possibly the best plan would be to state more or less chronologically what occurred. I happened to be present at the first gas attack and saw the whole gas business from the beginning. The first attack was made in April, 1915. A deserter had come into the Ypres salient a week before the attack was made, and had told us the whole story. They were preparing to poison us with gas, and had cylinders installed in their trenches. No one believed him at all, and no notice was taken of it.

Then came the first gas attack, and the whole course of the war changed. That first attack, of course, was made against men who were entirely unprepared—absolutely unprotected. You have read quite as much about the actual attack and the battle as I could tell you, but the accounts are still remarkably meager. The fellows who could have told most about it didn't come back. The Germans have claimed that we had 6,000 killed and as many taken prisoners. They left a battle field such as had never been seen before in warfare, ancient or modern, and one that has had no compeer in the whole war except on the Russian front.

What the Germans expected to accomplish by it I am not sure. Presumably they intended to win the war, and they might conceivably have won it then and there if they had foreseen the tremendous effect of the attack. It is certain that they expected no immediate retaliation, as they had provided no protection for their own men. They made a clear and unobstructed gap in the lines, which was only closed by the Canadians, who rallied on the left and advanced, in part through the gas cloud itself.

The method first used by the Germans, and retained ever since, is fairly simple, but requires great preparation beforehand. A hole is dug in the bottom of the trench close underneath the parapet, and a gas cylinder is buried in the hole. It is an ordinary cylinder, like that used for oxygen or hydrogen. It is then covered first with a quilt of moss, containing potassium carbonate solution, and then with sand bags. When the attack is to be made the sand bags and protecting cover are taken off the cylinder, and each cylinder is connected with a lead pipe which is bent over the top of the parapet. A sand bag is laid on the nozzle to prevent the back "kick" of the outrushing gas from throwing the pipe back into the trench. Our own methods are practically identical with those first used by the Germans.

The success of a cloud gas attack depends on thorough preparation beforehand. The attackers must know the country, the layout of the trenches, and the direction and velocity of the wind with certainty. Favorable conditions are limited practically to wind velocities between 12 and 4 miles an hour. A wind of more than 12 miles an hour disperses the gas cloud very rapidly. An upward current of air is the worst foe of gas. The weight of the gas is not an important factor in carrying it along, for it mixes rapidly with air to form the moving "cloud." The time occupied by a gas attack is too short to permit of much diffusion of the gas out of the original mixture.

The gas attack must be planned very carefully. If the trench line is very irregular it is likely that gas will flow into a portion of one's own trenches. The limits of safety in wind direction are thus determined by the direction of the lines of the trenches. The Germans use a 40° angle of safety; that means that on a given straight portion of the front the wind direction must lie between the two directions which make angles of 40° with the neighboring sections of the front. The most suitable type of country is where the ground slopes gently away from where the gas is being discharged. The Germans made one mistake in believing that hilly or wooded country would not do. This was refuted by the French, who made a successful gas attack in hilly and wooded country in the Vosges, as admitted in a captured German report. If the country is flat like that about Ypres, and the wind direction is right, there is very little difficulty about making an attack, especially if the enemy does not know anything about it. The element of surprise is important.

German gas attacks are made by two regiments of Pioneers, with highly technical officers, including engineers, meteorologists and chemists. They brought their first cylinders into the line without our knowing anything about it, except from the deserter's report which was not believed. The element of surprise was greatly lessened when we began to know what to look for and to recognize the sounds incident to the preparation of a gas attack.

The first attack was made with chlorine. If a gas attack is to be made with gas clouds, the number of gases available is limited. The gas must be easily compressible, easily made in large quantities, and should be considerably heavier than air. If to this is added the necessity of its being very toxic and of low chemical reactivity, the choice is practically reduced to two gases: chlorine and phosgene. Chlorine is to gas warfare what nitric acid is to high explosives. Pure chlorine did not satisfy quite all the requirements, as it is very active chemically and therefore easily absorbed. Many men in the first attack who had sufficient presence of mind saved themselves by burying their faces in the earth, or by stuffing their mufflers in their mouths and wrapping them around their faces.

There were several gas attacks of almost exactly the same kind early in 1915. There was no gas between the end of May, 1915, and December, 1915, and by that time adequate protection had been provided.

The first protection was primitive. It consisted largely of respirators made by women in England in response to an appeal by Kitchener. They were pads of cotton wool wrapped in muslin and soaked in solutions of sodium carbonate and thiosulfate; sometimes they were soaked only in water. A new type appeared almost every week. One simple type consisted of a pad of cotton waste wrapped up in muslin together with a separate wad of cotton waste. These were kept in boxes in the trenches, and on the word "gas" six or eight men would make a dive for the box, stuff some waste into their mouths, then fasten on the pad and stuff the waste into the space around the nose and mouth. But this got unpopular after a bit, when it was discovered that the same bits of waste were not always used by the same men. During the early part of 1915 this was the only protection used.

Then came the helmet made of a flannel bag soaked in thiosulfate and carbonate, with a mica window in it. A modified form of this device with different chemicals is still used in the British army as a reserve protection. It is put over the head and tucked into the jacket, and is fool-proof as long as well tucked down. This stood up very well against chlorine.

In 1915 we got word from our Intelligence Department of a striking kind. It consisted of notes of some very secret lectures given in Germany to a number of the senior officers. These lectures detailed materials to be used, and one of them was phosgene, a gas which is very insidious and difficult to protect against. We had to hurry up to find protection against it. The outcome was a helmet saturated with sodium phenate. The concentration of gases when used in a cloud is small, and 1 to 1,000 by volume is relatively very strong. The helmet easily gave protection against phosgene at a normal concentration of 1 part in 10,000. That helmet was used when the next attack came in Flanders, on the 19th of December. This attack was in many ways an entirely new departure and marked a new era in gas warfare.

There are three things that really matter in gas warfare, and these were all emphasized in the attack of December. They are: (1) increased concentration; (2) surprise in tactics; (3) the use of unexpected new materials.

Continued efforts have been made on both sides to increase the concentration. The first gas attack, in April, 1915, lasted about one and a half hours. The attack in May lasted three hours. The attack in December was over in thirty minutes. Thus, assuming the number of cylinders to be the same (one cylinder for every meter of front in which they were operating), the last attack realized just three times the concentration of the first, and six times the concentration obtained in May. Other cloud gas attacks followed, and the time was steadily reduced; the last attacks gave only ten to fifteen minutes for each discharge. We believe that the cylinders are now put in at the rate of three for every two meters of front, and may even be double banked.

The element of surprise came in an attack by night. The meteorological conditions are much better at night than during the day. The best two hours of the twenty-four, when steady and downward currents exist, are the hour between sunset and dark and the hour between dawn and sunrise. Gas attacks have therefore been frequently made just in the gloaming or early morning, between lights. This took away one of the easy methods of spotting gas, that of seeing it, and we had to depend upon the hissing noises made by the escaping gas, and upon the sense of smell.

Another element of surprise was the sending out of more than one cloud in an attack. After the first cloud the men would think it was all over, but ten minutes or half an hour later there would come another cloud on exactly the same front. These tactics were very successful in at least one case, namely, the attack near Hulluch in 1916. Some of the troops discarded their helmets after the first wave and were caught on the second, which was very much stronger than the first.

Efforts were also made to effect surprise by silencing the gas. But silencers reduced the rate of escape so greatly that the loss of efficiency from low concentration more than made up for the gain in suddenness. Another method was to mix the gas up with smoke, or to alternate gas and smoke, so that it would be difficult to tell where the gas began and the smoke ended.

The last attack made on the British by this means was in August, 1916. Since that time the Germans have used gas three times on the West Front against the French, and have also used it against the Italians and the Russians. It has been practically given up against the British, although the method is by no means dead.

The last attack was a slight set-back in the progress of gas defense. The casualties had been brought down to a minimum, and, as shown by the fact that the percentage of deaths was high, protection was complete in all cases where used, casualties being due to unprepar-

*Report of a lecture delivered before the Washington Academy of Sciences on January 17, 1918. Communicated by Dr. L. J. Briggs. Reported in the *Journal of the Academy*.

edness in some form. The attack in question was brought on under difficult conditions for the defenders, as it was made on new troops during a relief when twice as many men were in the trenches as normally. Furthermore, they had to wear helmets while carrying their complete outfit for the relief. This was the second time the Germans caught us in a relief, whether through information or luck we cannot say.

The protection that had been devised against phosgene proved effective at the time but provision was made to meet increased concentration of phosgene. We never had any actual evidence during the attack that phosgene was being used, as no samples were actually taken from the cloud, but cylinders os phosgene were captured later. Glass vacuum tubes, about 10 by 30 cm., with a tip that could be broken off and then closed by a plasticine-lined glass cap, were distributed, but the only one that came back was an unopened tube found in a hedge, and marked by the finder "Dangerous; may contain cholera germs." In a gas attack everybody keeps quiet or else has a job on hand, and conditions are not conducive to the taking of gas samples. The original types of vacuum tube were smaller than those now used.

There was a long search for materials that would absorb phosgene, as there are few substances that react readily with it. The successful suggestion came from Russia. The substance now used very extensively by all is hexamethylenetetramine (urotropine) $(CH_2)_6N_4$, which reacts very rapidly with phosgene. Used in conjunction with sodium phenate it will protect against phosgene at a concentration of 1:1000 for a considerable period. An excess of sodium hydroxide is used with the sodium phenate, and a valve is provided in the helmet for the escape of exhaled air. The valve was originally devised so that the hydroxide would not be too rapidly carbonated, but it was found in addition that there is a great difference in ease of breathing and comfort if a valve is placed in the mask. The helmet is put on over the head, grasped with left hand around the neck and tucked into the jacket. This form is still used in reserve.

By this time gas shells were beginning to be used in large numbers and it became evident that protection by a fabric could not be depended on with certainty. The box type of respirator was the next development. Respirators have to fulfill two requirements which are quite opposed to one another. In the first place they should be sufficiently large and elaborate to give full protection against any concentration of any gas, whereas military exigeucy requires that they be light and comfortable. It is necessary to strike a balance between these two. Upon a proper balance depends the usefulness of the respirator. Oxygen apparatus will not do on account of its weight and its limited life. Two hours' life is excessive for that type. The side that can first force the other to use oxygen respirators for protection has probably won the war.

The concentrations of gas usually met with are really very low. As has been said, a high concentration for a gas cloud is 1 part in 1000, whereas concentrations of two or three per cent. can be met by respirators depending on chemical reactivity. One such respirator is a box of chemicals connected by a flexible tube with a face-piece fitting around the contours of the face, and provided with a mouthpiece and nosepiece.

As regards the chemicals used there is no secret, for the Germans have many of the same things. Active absorbent charcoal is one of the main reliances, and is another suggestion that we owe to the Russians. Wood charcoal was used in one of their devices and was effective but most of the Russian soldiers had no protection at all.

We wanted to protect against chlorine, acids and acid-forming gases, phosgene, etc., and at one time were fearful of meeting large quantities of hydrocyanic (prussic) acid (HCN). At one period every prisoner taken talked about the use of prussic acid, saying that the Kaiser had decided to end the war and had given permission to use prussic acid. Protection was evidently needed against it. The three things that then seemed most important were: (1) chlorine and phosgene; (2) prussic acid; (3) lachrymators. Charcoal and alkaline permanganate will protect against nearly everything used, even up to concentrations of ten per cent. for short periods.

The German apparatus, developed about the same time, is of different pattern and is still employed. It consists of a small drum attached directly to the front of the face-piece, and weighs less than the British respirator but must be changed more frequently. It has no mouthpiece. The chemicals are in three layers: first an inside layer of pumice with hexamethylenetetramine, in the middle a layer of charcoal (sometimes blood charcoal) and outside baked earth soaked in potassium carbonate solution and coated with fine powdered charcoal.

As regards the future of the gas cloud it may be looked upon as almost finished. There are so many conditions that have to be fulfilled in connection with it that its use is limited. It is very unlikely that the enemy will be able to spring another complete surprise with a gas cloud.

The case is different with gas shells. The gas shells are the most important of all methods of using gas on the Western Front, and are still in course of development. The enemy started using them soon after the first cloud attack. He began with the celebrated "tear" shells. A concentration of one part in a million of some of these lachrymators makes the eyes water severely. The original tear shells contained almost pure xylyl bromide or benzyl bromide, made by brominating the higher fractions of coal-tar distillates.

The German did his bromination rather badly. As you know, it should be done very carefully or much dibromide is produced, which is solid and inactive. Some of the shells contained as much as 20 per cent. dibromide, enough to make the liquid pasty and inactive. The shells used contain a lead lining, and have a partition across the shoulder, above which comes the T. N. T. and the fuse. These shells had little effect on the British, but one attack on the French, accompanied by a very heavy bombardment with tear shells put them out badly. The eyes of the men were affected and many of the men were even anesthetized by the gas and were taken prisoner.

Our first big experience was an attack at Vermelles. The Germans put down a heavy barrage of these shells and made an infantry attack. The concentration was great, the gas went through the helmets and the men even vomited inside their helmets. But it is difficult to put down a gas barrage and there is danger that it will not be a technical success. In the instance cited certain roads were not cut off sufficiently so that reinforcements got up. This attack, however, opened our eyes to the fact that, as in the case of gas clouds, concentration would be developed so as to make it high enough to produce the required effect under any circumstances.

When the Germans started using highly poisonous shells, which was at the Somme in 1916, they did not attend to this sufficiently although enormous numbers of shell were used. The substance used was trichloromethyl-chloroformate, but not in great strength. It had no decided reaction on the eyes, hence the men were often caught.

The quantity of gas that can be sent over in shells is small. The average weight in a shell is not more than six pounds, whereas the German gas cylinders contain 40 pounds of gas. To put over the same amount of gas as with gas clouds, say in five minutes per thousand yards of front, would require a prohibitive number of guns and shells. It becomes necessary to put the shells on definite targets, and this, fortunately, the Germans did not realize at the Somme although they have found it out since.

The use of gas out of a projectile has a number of advantages over its used in a gas cloud. First, it is not so dependent on the wind. Again, the gunners have their ordinary job of shelling, and there is no such elaborate and unwelcome organization to put into the front trenches as is necessary for the cloud. Third, the targets are picked with all the accuracy of artillery fire. Fourth, the gas shells succeed with targets that are not accessible to high explosives or to gas clouds. Take, for instance, a field howitzer, dug into a pit with a certain amount of overhead cover for the men, who come in from behind the gun. The men are safe from splinters and only a direct hit will put the gun out of action. But the gas will go in where the shell would not. It is certain to gas some of the men inside the emplacement. The crew of the gun must go on firing with gas masks on and with depleted numbers. Thus it nearly puts the gun out of commission, reducing the number of shots say from two rounds a minute to a round in two minutes, and may even silence it entirely. Another example is a position on a hillside with dugouts at the back, just over the crest, or with a sunken road behind the slope. Almost absolute protection is afforded by the dugouts. The French tried three times to take such a position after preparation with high explosives and each assault failed. Then they tried gas shells and succeeded. The gas flows rapidly into such a dugout especially if it has two or more doors.

Among the effective materials used by the Germans for gas shells were mono- and tri-chloromethyl-chloroformate. Prussic acid never appeared; the Germans rate it lower than phosgene in toxicity and the reports concerning it were obviously meant merely to produce fear and distract the provisions for protection.

During the last five months the actual materials and the tactics used by the Germans have undergone a complete change. The lachrymator shells are less depended upon than formerly for "neutralization," but are still a source of annoyance. Mere annoyance, however, may be an effective method of neutralizing infantry. For instance, where large amounts of supplies and ammunition are being brought up there are always cross-roads where there is confusion and interference of traffic. A few gas shells placed there make every man put on his mask and if it is a dark night and the roads are muddy the resulting confusion can be only faintly imagined. It may thus be possible to neutralize a part of the infantry by cutting down their supplies and ammunition.

The use of a gas shell to force a man to put on his mask is practically neutralization. If at the same time you can hurt him so much the better. Hence the change in gas-shell tactics, which consists in replacing the purely lachrymatory substance by one that is also poisonous.

One substance used for this method of simultaneously harassing and seriously injuring was dichloro-diethyl-sulfide (mustard gas). Its use was begun in July of last year at Ypres, and it was largely used again at Nieuport and Armentieres. A heavy bombardment of mustard-gas shells of all calibers was put on these towns, as many as 50,000 shells being fired in one night. The effects of mustard gas are those of a "super-lachrymator." It has a distinctive smell, rather like garlic than mustard. It has no immediate effect on the eyes, beyond a slight irritation. After several hours the eyes begin to swell and inflame and practically blister, causing intense pain, the nose discharges freely, and severe coughing and even vomiting ensue. Direct contact with the spray causes severe blistering of the skin and the concentrated vapor penetrates through the clothing. The respirators of course do not protect against this blistering. The cases that went to the hospitals, however, were generally eye or lung cases, and blistering alone took back very few men. Many casualties were caused by the habit that some of the men had fallen into of letting the upper part of the mask hang down so as not to interfere with seeing. The Germans scored heavily in the use of this gas at first. It was another example of the element of surprise in using a new substance that produces new and unusual symptoms in the victims.

Up to the present time there has been no material brought out on either side that can be depended on to go through the other fellow's respirator. The casualties are due to surprise or to lack of training in the use of masks. The mask must be put on and adjusted within six seconds, which requires a considerable amount of preliminary training, if it is to be done under field conditions.

Among other surprises on the part of the Germans were phenylcarbylamine chloride, a lachrymator, and diphenylchloroarsine, or "sneezing gas." The latter is mixed in with high explosive shells or with other gas shells, or with shrapnel. It was intended to make a man sneeze so badly that when he puts on his mask he is not able to keep it on. The sneezing gas has, however, not been a very great success.

All bombardments now are of this mixed character. The shells used are marked with differently colored crosses and definite programs are laid down for the use of the artillerymen.

As regards the future of gas shells, it should be emphasized that the "gas shell" is not necessarily a gas shell at all, but a liquid or solid shell and it opens up the whole sphere of organic chemistry to be drawn upon for materials. The material placed inside the shell is transformed into vapor or fine droplets by the explosion and a proper adjustment between the bursting charge and the poisonous substance is necessary. Both sides are busy trying to find something that the others have not used, and both are trying to find a "colorless, odorless and invisible" gas that is highly poisonous. It is within the realm of possibilities that the war will be finished, literally, in the chemical laboratory.

The Germans have not altered their type of respirator for some time, and it is now equal in efficiency to the British or American respirator. The German respirator, even in its latest form, will break down at a concentration of 0.3 per cent. of certain substances. The German design has given more weight to military exigency, as against perfect protection, than has the British. Another thing that weighs against changes in design is the fact that the German, already handicapped by the lack of certain materials, must manufacture 40,000,000 respirators a year in order to supply his Austrian, Bulgarian and Turkish allies, as well as his own army.

In the British and American armies the respirator must always be carried with the equipment when within

12 miles of the front. Between 12 and 5 miles a man may remove the respirator box in order to sleep, but within 5 miles he must wear it constantly. Within 2 miles it must be worn constantly in the "alert" position (slung and tied in front). When the alarm is given he must get the respirator on within six seconds. The American respirator is identical with the British. The French have a fabric mask made in several layers, the inner provided with a nickel salt to stop HCN, then a layer with hexamethylenetetramine; it has no valve and is hot to wear. The French also use a box respirator, consisting of a metal box slung on the back with a tube connecting to the face mask; the latter is of good Para rubber and is provided with a valve. One disadvantage of this form is the danger of tearing the single rubber sheet. The German mask now contains no rubber except one washer; the elastics consist of springs inside a fabric and the mask itself is of leather. It hardens and cracks after being wet and is too dependent upon being well fitted to the face when made.

(The lecturer exhibited various types of gas shells, helmets, masks and respirators.)

The following compounds have been used by the Germans in gas clouds or in shells:

1. Allyl-iso-thiocyanate (Allyl mustard oil), C_3H_5NCS (shell).
2. Benzyl bromide, $C_6H_5CH_2Br$ (shell).
3. Bromo-acetone, $CH_2Br.CO.CH_3$ (hand grenades).
4. Bromated methyl-ethyl-ketone (bromo-ketone), $CH_2Br.COC_2H_5$ or $CH_3CO.CHBr.CH_3$ (shell). Dibromo-ketone, $CH_3COCHBr.CH_2Br$ (shell).
5. Bromine, Br_2 (hand grenades).
6. Chloro-acetone, $CH_2Cl.COCH_3$ (hand grenades).
7. Chlorine, Cl_2 (cloud).
8. Chloromethyl-chloroformate (PaHte), $ClCOOCH_2Cl$ (shell).
9. Nitro-trichloro-methane (Chloropicrin or nitrochloroform), CCl_3NO_2 (shell).
10. Chlorosulfonic acid, $SO_2.H.Cl$ (hand grenades and "smoke pots").
11. Dichloro-diethylsulfide (mustard gas), $(CH_2Cl-CH_2)_2S$ (shell).
12. Dimethyl sulfate, $(CH_3)_2SO_4$ (hand grenades).
13. Diphenyl-chloro-arsine, $(C_6H_5)_2AsCl$ (shell).
14. Dichloromethyl ether, $(CH_2Cl)_2O$ (shell).
15. Methyl-chlorosulfonate, CH_3ClSO_3 (hand grenades).
16. Phenyl-carbylamine chloride, $C_6H_5NCCl_2$ (shell).
17. Phosgene (carbonyl chloride), $COCl_2$ (cloud and shell).
18. Sulfur trioxide, SO_3 (hand grenades and shell).
19. Trichloromethyl-chloroformate (Diphosgene, superpalite), $ClCOOCCl_3$ (shell).
20. Xylyl bromide (tolyl bromide), $CH_3C_6H_4CH_2Br$. (shell).

Platinum in the Ural Region

THE following points concerning platinum have been furnished by Prof. Louis Dupare of the Geneva University, who is an eminent specialist in all researches about this metal, having spent a long period in the Ural region in connection with geological explorations as well as extraction of the metal. He commenced this work in 1900, starting with the Koswinsky-Kamen platinum field, and after a considerable time he came to the conclusion that this metal occurred only in a basic rock known as dunite. He then made explorations over the vast regions of the North Ural and studied all the known deposits in the Ural region, after which he modified his first opinion, for he found that platinum also occurs in another rock, pyroxenite; but with dunite, these appear to be the only rocks containing platinum. This metal is also found in streams and in alluvial soil. The dunite rock may be said to invariably contain platinum wherever it is found, but the pyroxenites only contain it under certain conditions.

Very few persons have ever seen platinum in the native state imbedded in the rock, and specimens of this kind are extremely rare. In the case of dunite, platinum is seen in two general forms, first, crystallized directly in the rock along with the rock material, or second, crystallized with chromite and consequently localized in the regions where this mineral occurs in the rock. This second case is the most frequent, no doubt. In dunite, platinum is found either in small isolated crystals or in masses of a certain size which in certain cases are set free from the rock and roll in the water courses in the shape of small nuggets. In chromite (one of the constituents of dunite rock) the platinum crystals are found either disseminated irregularly in the masses of chrome iron or else the platinum forms an intermeshed structure with this mineral, in which the chromite parts are held together by the platinum which acts as cement and follows the contours of the mineral parts. In this way the platinum makes up a veritable sponge, with the mineral lodged in the cavities, as can be seen by making a section of the rock, and the role played by the platinum in uniting the chromite crystals is very clearly observed.

The disposition of the metal in the pyroxenite rocks is quite analogous to the preceding, and two general forms are also noted; first, the platinum is crystallized directly with the pyroxene, and second, it is associated with the magnetite which forms aggregations in the rock. It is more difficult to find platinum in this rock than in dunite. But, in the Gussewa region, there are often found nuggets in which the metal is seen associated with the rock, and this allows of making good observations. The platinum is seen molded around the large pyroxene crystals after the manner of a cement, and when the crystals disappear because of an alteration produced in the alluvion, their imprints can be clearly seen in relief in the platinum; and this is the cause of the irregular and hollow shapes of certain nuggets of pyroxene origin. Because the platinum appears as a more recent or consolidating element, holding the crystal parts of the rock together, it should have a lower melting point than these rocks. However, chromite melts at 1,840 degrees C. and the other minerals still lower. But the melting point of platinum is usually given as about 2,000 degrees. This apparent contradiction may be explained by the fact that (as the author demonstrates) native platinum is not a pure element but a complex alloy, and it is well known that alloys melt at a lower point than their component metals.

The principal natural alloys of platinum contain the following metals, but these are in very variable proportions. Osmo-iridium is the first of the series, and this term includes definite compounds of osmium, iridium and always a certain amount of ruthenium. But it is to be noticed that the osmo-iridium is not in reality alloyed with the platinum, but its masses are surrounded by the latter metal, so that the former appears as if imbedded in it. Here the osmo-iridium forms flat hexagonal crystals. Iridium is found alloyed with platinum in variable proportions which sometimes reach 5 or 6 per cent. Rhodium, which is closely related to iridium, is nearly always seen in the various native alloys, but always in a low degree, not over 0.3 to 1.0 per cent. Palladium is a constituent of all the natural alloys of platinum, but it rarely exceeds 0.5 per cent. While it is true that gold is often found in native platinum, it is often claimed that it comes from a foreign source and has nothing in common with a natural alloy. In fact in the Ural regions it is rare to find gold, and the proportion is very small as seen in platinum grains selected under the hand glass. But in British Columbia there are found platinum nuggets shot with native gold, and this is a proof that gold may exist in the form of an alloy. Copper is constantly found in the native alloys in proportions varying from 0.1 to 5.0 per cent and nickel is of very frequent occurrence, but only in small quantities, and never over 1 per cent. After platinum itself, iron is the metal which occupies the most important place. The amount is quite variable, and this lies between 3 and 20 per cent. Because of the presence of iron, such alloys are more or less magnetic, and two kinds can be distinguished; the ferro-platinum, which is usually attracted by the magnet, and the polyxene, which is not so attracted, so that the native platinum can be run under the magnet and separated into two parts, in variable amounts of course, according to the case. For instance, at Taguil, nearly all the metal is attracted, while at Kitlim only a small part can be attracted by the magnet. Native platinum grains or nuggets are treated by aqua regia, which dissolves all the metals except the osmo-iridium, which is left as a crystalline powder. When the osmo-iridium is very abundant, for instance in some of the nuggets, the platinum can be dissolved away so as to leave a veritable sponge formed of osmo-iridium in flat crystals. Simply as an example—for the figures vary widely—we note a percentage analysis of native platinum. Osmo-iridium 1.50; platinum 77.16; iridium 2.68; rhodium 0.54; palladium 0.27; gold 0; copper 3.39; nickel, (traces); iron 14.72 per cent. This specimen is selected as showing the entire number of metals in its make-up, except gold, which however occurs in some other specimens. In another case there were only four metals present, which appears to be the minimum for the various analyses given by the author.

Inducing Rain by Electricity

WHILE we on this side of the world are chiefly interested in the prevention of rainfall, in Australia the reverse holds good, and experiments are being carried out "down under" with an electrical plant for the purpose. The experiments carried out are said to be effective. According to a Sydney newspaper, careful research showed the inventor, Mr. Balsillie, that in fine weather there was a charge of positive electricity in the higher regions of the air, and that when it rained negative electricity predominated. He was studying the effects of mountains on rainfall, and came to the conclusion that hills acted as conductors of the negative electrical energy with which the earth's surface is charged. He argued that all that was necessary, therefore, to give flat plains the same advantage as regards rainfall as hilly country, was the free passage of the negative electricity to the higher regions of the air. His rainmaking plant now consists of a set of two or three kites, which are let up on galvanized flexible wire to an altitude of between 4,000 feet and 6,000 feet. The negative current is taken from the earth by means of a terminal, which is well grounded. Of course, the first essential in the business is wind. In his tests at Bookaloo and elsewhere, Mr. Balsillie has found that rain invariably falls after the kites have been in the air for from six to ten hours. In addition to the testing station on the Transcontinental Railway line, another station is being established in the Northern Territory for Government experimental work.—*The Engineer*.

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, MARCH 2, 1918

Published weekly by Munn & Company, Incorporated
Charles Allen Munn, President; Frederick Converse Beach, Secretary; Orson D. Munn, Treasurer
all at 233 Broadway, New York

Entered at Post Office of New York, N. Y., as Second Class Matter

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The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) 4.00
The combined subscription rates and rates to foreign countries including Canada, will be furnished upon application.
Remit by postal or express money order, bank draft or check.

Munn & Co., Inc., 233 Broadway, New York

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Table of Contents

	PAGE
Technical History of the Airplane.—By Capt. F. M. Green..	130
Mosquitoes and Swamp Fever at Paris	131
Drying Vegetables a New Conservation Move.—By Arthur L. Dahl.—3 illustrations	132
Our Sun and Other Sky-Furnaces.—By Charles Nevels Holmes.—1 diagram	133
Are Concrete Ships Desirable?	133
Modern Margarine Technology.—By W. Clayton	134
Indian Sumach	135
Evolution of Time-Marking Devices.—By Percy Collins.—11 illustrations	136
Is the Sun Due to Explode?	137
Deglet-Knour	137
Photographic Printing Method	137
The Divining Rod.—II.—By Arthur J. Ellis	138
Insects That Eat Tobacco	139
Method of Observation and Measurement of Rapid Periodic Magnetic Phenomna	139
Development by X-Ray of Two New Fields.—By L. C. Dodd.—3 diagrams	140
Gas Warfare.—By S. J. M. Auld	142
Platinum in the Ural Region	144
Inducing Rain by Electricity	144